

# CREATING AN INTEGRATED WEED MANAGEMENT PLAN

**A Handbook for Owners and Managers of Lands  
with Natural Values**

*Caring for the Land Series*  
**Volume IV**

**March 2000**



Colorado Natural Areas Program  
Colorado State Parks  
Colorado Department of Natural Resources



Division of Plant Industry  
Colorado Department of Agriculture



Cover illustration: Leafy spurge (*Euphorbia esula*)

**State of Colorado**  
*Bill Owens, Governor*

**Colorado Department of Natural Resources**  
*Greg E. Walcher, Executive Director*

**Colorado State Parks**  
*Laurie A. Mathews, Director*

# TABLE OF CONTENTS

ACKNOWLEDGMENTS .....	iii
FOREWORD .....	v
I. INTRODUCTION .....	1
What is a Weed? .....	2
Why Should We Be Concerned About Weeds? .....	3
Weed Law .....	5
Weed Management Strategies.....	5
Adaptive Management Strategy.....	5
Objective and Scope of This Handbook .....	6
How to Use This Handbook.....	7
II. DESCRIBING YOUR PROPERTY OR MANAGEMENT AREA.....	9
Defining the Property or Management Area.....	9
Delineating the Property or Management Area Boundaries .....	9
Identifying Resources on Your Property .....	13
III. INVENTORYING YOUR PROPERTY OR MANAGEMENT AREA FOR WEEDS .....	17
Preparing for Field Work .....	17
Searching for Weeds.....	18
Mapping Weed Infestations .....	20
IV. LAND MANAGEMENT GOALS AND WEED MANAGEMENT OBJECTIVES .....	25
Management Goals .....	25
Weed Management Objectives .....	27
V. PRIORITIES FOR WEED MANAGEMENT .....	29
Priority Weed Species .....	29
Ranking Weed Species .....	30
High-Priority Weed Infestations .....	33
Low-Priority Weed Infestations.....	34
VI. WEED MANAGEMENT TECHNIQUES.....	36
Prevention .....	37
Pulling.....	41
Mowing and Cutting .....	42
Cultural Controls.....	44
Livestock Grazing .....	46
Biological Control Agents (Insects).....	47

Herbicides .....	49
Prescribed Burning.....	53
VII. INTEGRATED WEED MANAGEMENT .....	55
General Principles .....	55
General Strategies .....	58
IWM Examples .....	59
Putting it All Together .....	67
VIII. MONITORING AND EVALUATION .....	73
Steps in a Monitoring Program .....	74
Setting Monitoring Priorities .....	75
Designing Monitoring Actions .....	75
Estimating Weed Abundance.....	78
Test Monitoring Actions .....	81
Implement Monitoring .....	81
CONCLUSION.....	83
REFERENCES .....	84
APPENDICES:	
1. Sources of Additional Information .....	87
2. List of County Weed Supervisors .....	93
3. Weed Management Plan Outlines .....	95
4. Profiles of Colorado State Listed Noxious Weeds .....	117
5. Colorado Noxious Weed Act (including list of state noxious weeds) and Weed Free Forage Act .....	273
6. Alien Plants Ranking System (Version 5.0) and Alien Plants Ranking System Answers Table .....	301
7. Weed Abundance and Monitoring Data Sheets .....	307
8. Biological Control Insects Available From State Insectary .....	311
9. Herbicide Basics and Herbicide Trade Names and Active Ingredients .....	315
10. Herbicide Use Guidelines .....	321
11. Susceptibility of Some Colorado Weeds to Picloram, Dicamba, 2-4D, and Glyphosate .....	327
12. Plant Basics .....	331
13. Collecting and Pressing Plants .....	337
14. Glossary of Terms .....	339

# ACKNOWLEDGMENTS

This handbook is the product of many months work by a number of people. The idea to produce such a book originated with Mark Gershman, former director of the Colorado Natural Areas Program. Mark and Colorado State Weed Coordinator Eric Lane took the initiative in the development and funding of the project, and together with Faye Koeltzow (Colorado State Parks) developed an outline and recruited an advisory group of weed management experts from around the state. During the subsequent development and publication of the handbook, many people made valuable contributions, and the Colorado Natural Areas Program extends its appreciation to all these contributors.

Alan T. Carpenter and Thomas A. Murray of Land Stewardship Consulting, Inc. in Boulder, CO wrote and assembled the first complete draft of the handbook. Karin Decker edited and produced the final draft. Further content and editorial services were provided by Rita Berberian, Rob Billerbeck, Kathy Carsey and Janet Coles, of the Colorado Natural Areas Program. Weed illustrations are by Mary Bonnell.

Funding for the development, publication and distribution of this handbook was provided by:



GOCO - Great Outdoors Colorado



Division of Plant Industry  
Colorado Department of Agriculture



The Colorado Natural Areas Program  
Colorado State Parks  
Colorado Department of Natural Resources



National Fish and Wildlife  
Foundation

This handbook has undergone extensive review by many knowledgeable people. However, the handbook still may contain errors. In addition, weed management is a rapidly changing field, and new techniques and insights are being developed continually. Readers are advised to consult with their county weed supervisors and other knowledgeable people to confirm statements that appear in this volume and to obtain the most up-to-date information available.

The views and conclusions contained in this document are those of the authors and should not be interpreted as representing the opinions or policies of the State of Colorado. Mention of trade names or commercial products does not constitute their endorsement by the State of Colorado.

The following individuals contributed valuable information and feedback, and we gratefully acknowledge their help in the compilation of this handbook..

**Steve Anthony.** Garfield County

**Julie Arington.** Castlewood Canyon State Park

**K. George Beck.** Colorado State University

**Alex Birchfield.** Florissant Fossil Beds National Monument

**Jim Borland.** Denver, CO

**Ron Broda.** Weld County

**Bill Burrows.** Burrows Ranch Hunting Club, Red Bluff, CA

**Jeff Connor.** Rocky Mountain National Park

**Michael Craig.** Pitkin County

**Colorado Natural Heritage Program staff.** Fort Collins, CO

**Carol Dawson.** Denver Botanic Gardens

**Laurie Deiter.** City of Boulder Open Space Department

**Debbie Eberts.** Bureau of Reclamation, Denver, CO

**Bill Goosmann.** Fort Collins, CO

**Adena Green.** Gunnison County

**Heather Knight.** The Nature Conservancy

**Angela Medbery.** Denver, CO

**Jody K. Nelson.** Exponent

**Cindy Owsley.** Boulder County Parks and Open Space

**Heather Poe.** Roxborough State Park

**Chad Reid.** Utah State University Cooperative Extension

**Tim Seastedt.** University of Colorado, Boulder

**Jim Smith.** Chatfield State Park

**Lisa Tasker.** Central Rockies Chapter, Society for Ecological Restoration

**Dave Weber.** Colorado Division of Wildlife

# FOREWORD

Sometime in 1998, Mark Gershman, the director of the Colorado Natural Areas Program, approached me about developing a guide for Colorado landowners regarding noxious weed management as part of the Caring for the Land Series. The Colorado Natural Areas Program had been building a library of outreach publications and concern was mounting that many of Colorado's treasured natural areas and wildlands were in jeopardy from the ongoing or inevitable invasion of noxious weeds. Indeed, Coloradans have made great strides in protecting their natural heritage and open spaces from development: Colorado's 36 national, regional, statewide and local land trusts have protected more than one-half million acres in the state. Nevertheless, many of these protected lands are threatened with permanent degradation or destruction by invasive plants. Unfortunately, the threat is often realized as a consequence of lack of information, poorly targeted actions or a failure to implement a long-term management plan. To help remedy this situation, Mark suggested developing a guide for landowners, especially those with natural areas, that would bring together information to develop and implement successful long-term weed management.

Coincidentally, I had been charged by the Colorado Legislature in 1996 to prepare "a recommended management plan for the integrated management of designated noxious weeds within state-owned lands." When one stops to consider the types of lands owned by the State of Colorado, the vast majority of them, aside from public rights-of-way, are "natural" in character. These lands include the numerous wildlife refuges managed by the Colorado Division of Wildlife, the many forests and rangelands overseen by the State Board of Land Commissioners, and the 40+ parks maintained by the Division of Parks and Outdoor Recreation. In all, the state of Colorado owns and oversees several million acres of land whose agricultural productivity, bountiful wildlife and recreational benefits depend upon healthy, native plant communities. Consequently, these public natural areas and the benefits Coloradans derive from them are jeopardized by noxious weeds. Clearly, it is not feasible to develop a single management plan for several million acres scattered about Colorado. Colorado's topography, climate, soils, plant communities, and the many purposes to which state lands are put simply vary too much across the state to develop any single meaningful plan. Rather, what seems more vital and feasible (and in keeping with the Colorado Legislature's spirit regarding noxious weeds and its tradition of providing resources to local communities) is to provide state land managers with a template and the tools necessary to develop property-specific plans that fit the conditions and resources of each state-owned property in Colorado.

As Mark and I discussed our needs it soon became clear that together we could produce a handbook that provides the tools and information necessary for public and private landowners to successfully manage noxious weeds in natural areas, wildlands and rangelands. While much has been studied and documented regarding weed management in an intensive agricultural setting, relatively little has been prepared regarding the management of weeds in a wildland setting. Increasingly, Colorado's public and private wildland owners and managers face the inevitable

prospect that with land ownership comes responsibility for land stewardship. To some, this comes naturally, to others much less so. As noxious weed species continue to invade our state and our natural communities, it is becoming increasingly important for all landowners to take control and manage invasive species. This handbook was designed for both public and private landowners who are struggling to address the management nightmares of noxious weed invasions. For landowners and managers with no or relatively little weed management experience, we have endeavored to present information regarding the philosophy and practice of weed management in a chronological fashion which will lead you through the process of developing and implementing an effective weed management plan for your lands. For those with more experience, we have included additional information and references to numerous resources that may be difficult to find and obtain without considerable effort. Indeed, much of the material in this handbook is not original. Rather, it has been culled from a variety of sources and edited into a logical and useful format that we believe represents some of the best information currently available regarding the management of noxious weeds.

In the process of developing this handbook, we have made a conscious effort always to keep our readers in mind and to provide current information in a useful format. While factual information rapidly becomes obsolete with new research or greater experience, much of our understanding regarding the philosophy and practice of integrated weed management shall remain cornerstones of effective weed management. We fully anticipate revising and improving upon this document as new information and ideas come to light and as time and budgets allow. Consequently, we would like you, the reader and weed management practitioner, to contribute suggestions, corrections, and ideas so that we may improve upon this first attempt at a weed management handbook for natural areas and wildlands. With your experience and contributions to weed management on your land and in your community, we can all hope for an improved and increasingly useful weed management planning guide that will benefit novice and experienced land stewards alike.

*Eric Lane*  
*State Weed Coordinator*  
*State of Colorado*

# I.

## INTRODUCTION

One of the most serious and fastest growing problems in the West today is the spread and establishment of invasive non-native plants. Noxious weed infestations have contributed to the loss of agricultural productivity and ecological functions on both public and private lands, including some of Colorado's most valuable and productive wildlife habitat. Weeds are rapidly becoming the most pressing management issue for many private landowners and public land managers. Although most lands in Colorado harbor some weedy alien plants, in many cases labor and funds are insufficient to permit control of all weedy species. As a result, landowners and managers must, at least temporarily, choose which species to control while leaving others uncontrolled. Current and complete information on weedy species and control practices is a vital requirement for making these choices. Unfortunately, such information is often inadequate or difficult to obtain outside the scientific community.

This handbook is intended to address that shortcoming. By using a structured, logical approach to weed management, based on the best available information, land managers and owners should be able to protect and enhance the value of their properties. This handbook presents a series of steps for the preparation of an integrated weed management plan which is tailored to a specific site. The use of such a plan will enable managers and owners to be more efficient and cost effective at controlling weeds.

Basic steps in developing an integrated weed management plan, covered in this handbook:

- Describe the property
- Inventory the property for weeds
- Formulate management goals and objectives
- Set priorities for weed management
- Select management actions
- Develop an integrated weed management plan
- Develop a monitoring plan

Control weeds!

This handbook focuses on the management of lands that are primarily natural in character. Colorado state law provides for a system of designated natural areas, as well as a Natural Areas Program (Colorado Natural Areas Act, 33-33 C.R.S. 1984). These officially designated areas preserve some of the finest examples of Colorado's original and unique landscapes for the benefit of present and future generations. Although only a small fraction of Colorado's lands are state-designated natural areas, vast areas of private and public land in Colorado are primarily natural in character and support many of the same resources preserved in designated natural areas. In the context of this handbook, "natural" includes nearly all rangelands, shrublands and forests in Colorado, not just officially designated "Natural Areas." Although many of the principles described here may apply, this handbook is not designed for use in the management of croplands, industrial sites, or highway rights-of-way. Such situations are typically highly unnatural and extensively manipulated. In these cases the weed management approach presented in this handbook may not be appropriate.

Colorado's natural lands are a critical component of our state's economy and quality of life. Unfortunately, all natural lands and the native plant communities they support are threatened by invasive alien weeds. Managing weeds must be a high priority of natural area and natural resource management. Labor and financial resources are not and will not be sufficient to eradicate all invasive weeds. Therefore, it is critical to use our limited resources in such a manner as to focus control efforts where they will do the most good. This handbook is intended to assist Colorado's private landowners and public land managers in their weed management endeavors. Because the health of native plant communities is often closely tied to the spread of invasive exotic species, this handbook is also meant to serve as a companion volume to the *Native Plant Revegetation Guide*, also published by the Colorado Natural Areas Program.

## WHAT IS A WEED?

The term "weed" enjoys almost universal recognition among English-speaking people, even though there is no universally accepted definition of the word. John Randall, the national weed expert of The Nature Conservancy, discussed numerous definitions in his review of the subject (Randall 1997). A common theme in most of the definitions is the notion of a plant growing where it is not wanted. A plant species may be desirable in one situation (e.g. grass in a lawn) and undesirable and therefore a weed in another situation (e.g. grass in a vegetable garden).

Randall suggests that in the case of natural lands, a weed is a plant which prevents the accomplishment of management goals. That is, the importance of a weed is measured by its impact on a site and by its interference with the landowner's management goals. By this definition, a plant is not necessarily a weed simply because it is not indigenous to a site. By the same token, some landowners consider certain native species to be weeds. For example, ranchers may regard native larkspur and locoweed as weeds because these plants can poison livestock. However, most managers of natural areas would view these same species as integral components of plant communities which they wish to maintain. When seeking outside advice on weed management, **remember that experts and consultants may have differing ideas about which plants are weeds, and that these definitions may not agree with your own ideas.**

The terms alien, nonnative, and exotic are all terms used to describe species that have been introduced to an area.

For the purposes of this handbook, weeds are defined as those alien plant species which are listed as "noxious" pursuant to the Colorado Noxious Weed Act (C.R.S. 35-5.5). This definition applies to plant species listed by the state, counties, and municipalities. Noxious weeds are generally more detrimental to natural lands than other problem plants, and are those that landowners are required by law to control.

See Appendix 5 (page 273) for the complete text of the Act, as well as a list of the State Noxious Weeds. Currently, sixty-seven plant species are included on this list. All of these species are non-native plant species that create problems in agriculture and the environment. However, some of these species are confined to highly disturbed sites or areas that are farmed and typically do not occur in rangelands, shrublands, forests or on other natural lands in Colorado.

**“Noxious weed” means an alien plant or parts of an alien plant that have been designated by rule as being noxious or has been declared a noxious weed by a local advisory board, and meets one or more of the following criteria:**

- **Aggressively invades or is detrimental to economic crops or native plant communities;**
- **Is poisonous to livestock;**
- **Is a carrier of detrimental insects, diseases, or parasites;**
- **The direct or indirect effect of the presence of this plant is detrimental to the environmentally sound management of natural or agricultural ecosystems.**

**Colorado Revised Statutes 35-5.5-103**

## WHY SHOULD WE BE CONCERNED ABOUT WEEDS?

The effects of weed infestations are widespread and affect many aspects of our lives.

### ECOSYSTEM PROCESSES

Weeds can drastically alter the ecological checks and balances that have developed over thousands of years. The growth and spread of weeds can alter fire patterns and intensity, resulting in major ecosystem changes. Cheatgrass has so altered the fire regime of the Great Basin that re-establishing native plant communities in some areas is essentially impossible (Whisenant 1989, Mosely et al. 1999). Some nitrogen-fixing plant species increase soil nitrogen levels to the point that other non-native plant species outcompete native species that have evolved in nutrient-poor soils (Vitousek 1986). Weeds can affect soil erosion and aquatic habitat in nearby streams and ponds. A spotted knapweed study showed that runoff increased by 56% on areas infested by spotted knapweed and that sediment yield increased by 192% (Lacey et al. 1989).

### WILDLIFE

Many alien plant species provide poorer habitat for wildlife species and livestock than their displaced native counterparts. Studies in Montana showed a 98% decrease in elk use of a bunchgrass range and a 67% decline in carrying capacity after spotted knapweed took over (Hakim 1979). Tamarisk and Russian olive thickets along rivers provide much poorer wildlife habitat than native cottonwood and willow communities (Carpenter 1997, Knopf and Olson 1984).

### AGRICULTURE

Weeds create large economic losses for agriculture in both cropland and rangeland situations. Weeds can reduce the production of forage for livestock by crowding out palatable species. Some species like St. Johnswort, Russian knapweed and leafy spurge are toxic to livestock.

Ranches that have been infested by leafy spurge sometimes now sell at a fraction of their values prior to leafy spurge infestation (Olson 1999).

## BIOLOGICAL DIVERSITY

Noted biologist Edward O. Wilson of Harvard University has stated “Alien species are the stealth destroyers of the American environment.” He believes that competition from invasive species is the main cause of decline in 18% of endangered species and contributes to the loss of an additional 24% of these species. According to Wilson, impacts from invasive species are second only to direct destruction of habitat as a cause of species decline (Wilson 1999). Weeds can displace native plant species. Russian knapweed has pushed out native plant species on more than a million acres of land in the United States (Whitson 1999). Some non-native species release substances in the soil that prevent re-establishment of native species. For example, tamarisk can increase the salinity of soils to the point that native willows and cottonwoods cannot grow any longer.

## PUBLIC LANDS

Nonnative plants colonize an estimated 4600 acres of federal lands each day, amounting to an area the size of the state of Delaware each year. Invasive plants currently infest an estimated seven million acres of National Parks system lands, in spite of spending millions of dollars each year combating invasive species (National Park Service 1996). Between six and seven million acres of National Forest lands across the United States, including more than 250,000 acres in Colorado, are infested with noxious weeds, and this level is increasing at a rate of 8-12% per year (Hiebert and Stubbendieck 1993). Noxious weeds are increasing on BLM lands at a rate of approximately 2,300 acres per day (National Park Service 1996).

## RURAL SUBDIVISIONS

While weeds have long been a bane of agriculture, they have generally not been a problem for urban or suburban landowners except in vegetable and flower gardens. However, this situation is changing as ranches are converted to large-lot subdivisions, especially where horses or livestock are grazed on small tracts of land. Weeds affect local wildlife, invade open space and poison horses. New rural landowners are discovering that managing weeds is one of the responsibilities of land ownership. Unfortunately, many of these landowners don't have detailed knowledge about weeds.

### The Essence of Noxious Weed Management

Noxious weed management is a good neighbor policy. One should be neighborly and manage the noxious weeds infestations on their land. However, if one's neighbor refuses to manage their noxious weeds, that is no excuse to repeat their error. While it may be frustrating when a landowner manages their noxious weeds and their neighbor does not, it is never futile!

K.George Beck  
Associate Professor of Weed Science  
Colorado State University

One of the reasons for preparing and implementing a weed management plan for your property is to be a good neighbor. Being a good neighbor requires landowners and managers to be alert for new weed infestations and to control existing infestations. Weed management

is also much more successful if neighbors join together to control weeds that readily spread from place to place. Although private landowners and public land managers may have different perspectives on weeds, they share the common goal of protecting their property or management area from the negative effects of noxious weeds.

## WEED LAW

In recognition of the economic and ecological impacts of weeds, the State of Colorado adopted the Colorado Weed Management Act (also known as the Colorado Noxious Weed Act) in 1990. The act requires landowners and managers to manage noxious weeds if those weeds are likely to damage neighboring lands. The act stipulates that each county and municipality in Colorado must adopt a noxious weed management plan for its jurisdiction. Each county and municipality also appoints an advisory board to develop weed management plans and to identify certain plant species as noxious weeds for its area. Lists of plants that have been designated “noxious” in a particular jurisdiction are available from county weed supervisors (see Appendix 2 on page 93). Landowners and managers are responsible for controlling these identified damaging species. If they fail to do so, the county or municipality may legally enter the property, control weeds, and charge the landowner for the cost of control work.

## WEED MANAGEMENT STRATEGIES

Weed control should be part of the management program for any property. This handbook advocates the creation of management goals which focus on preserving and establishing desired species and natural communities rather than simply eliminating weeds. Landowners should:

- **Implement preventive efforts** to keep a property free of weeds which are not yet established but which are known to be present elsewhere in the area.
- **Set priorities for control and elimination** of weeds which are already established, according to their actual and potential impacts on the management goals for the property or management area.
- **Take prompt action** when careful consideration indicates that leaving a weed species unchecked will be more damaging than controlling it with available methods, and when a species is locally listed as “noxious.”

## ADAPTIVE MANAGEMENT STRATEGY

Landowners should use an adaptive management strategy in dealing with weeds. In this approach the landowner or manager considers weed management to be an on-going process where the outcome of control efforts may vary. There are six steps in an adaptive management process:

1. Establish and record management goals and weed management objectives.
2. Identify weed species which block the completion of these goals, and assign priorities to these species based on the severity of their impact and the difficulty of control.

3. Consider methods for controlling high priority species and infestations, or otherwise reducing their impact. If necessary, reprioritize based on likely impacts of control actions on target and non-target species, ecosystem functions and agricultural productivity.
4. Develop weed control plans based on this information, and implement them.
5. Monitor the results of management actions and evaluate the results in light of the management goals for the property.
6. Modify and improve control priorities, methods and plans according to the information gained through monitoring, and start the cycle again.

Use of this type approach should increase the effectiveness of a weed control program over time.

## OBJECTIVE AND SCOPE OF THIS HANDBOOK

This handbook provides step by step information on how to prepare an integrated weed management plan for a particular property or management area. It is also designed to serve as a reference source of information about weeds, to be used in conjunction with other weed information resources. The bulk of the handbook consists of a series of appendices covering topics such as detailed information on each Colorado noxious weed species, weed management plan outlines, alien plant ranking systems, herbicides, and much more. Most users will not need to read every part of this material, but only that which is applicable to their particular circumstances.

Because private landowners and public land managers normally face somewhat different weed management challenges, much of the information in the introductory part of the handbook is presented from two separate viewpoints, and two types of generic plan outline are provided (Appendix 3). In general, private landowners control smaller properties than public land managers and do not need to document their decisions to the same extent as do public land managers. Therefore, the plan outline for private landowners is shorter and simpler than the public land manager's form. Of course, users may employ whichever outline best suits their purpose, or modify either outline to address a particular situation.

Although the information in this handbook was current at the time of printing, users should be aware that new and updated information is constantly becoming available. Please consult your county weed supervisor to obtain the latest information. This handbook as well as updates will be available via the Internet at <http://cnap.state.co.us/publications.html> and at <http://www.ag.state.co.us/DPI/>. Please check these sites periodically for updates to the handbook.

## HOW TO USE THIS HANDBOOK

This handbook is intended to serve as a guide to the steps necessary to prepare an integrated weed management plan.

First, read the introductory material and skim through the following chapters once to understand the general approach and to note the information you will need to prepare a weed management plan. Sentences marked with ☒ indicate a specific action needed in the preparation of the plan.

Prepare your plan using the appropriate form in Appendix 3 (page 95) and the following steps, reading the corresponding chapter in the handbook as you go:

- Describe the property or management area
- Inventory the property or management area for weeds
- Develop land management goals and weed management objectives
- Set priorities for weed management
- Consider weed management actions
- Compile an integrated weed management plan
- Develop a monitoring system

Depending on how much you already know about the weeds on your property or management area, you may need to stop and collect information about weeds you manage and locations on your property. However, if you the owner or manager of a smaller property and are already familiar with the weeds on your property you should be able to prepare a draft weed management plan in less than one day using the approach and information presented in this handbook.



## **II.**

# **DESCRIBING YOUR PROPERTY OR MANAGEMENT AREA**

In order to organize an effective weed management strategy it is essential to have a clear idea of the natural resources on your property and a means of mapping weed populations. Therefore, the first steps in the preparation of a weed management plan are to define the area to be managed, and to acquire a map of the property.

## **DEFINING THE PROPERTY OR MANAGEMENT AREA**

Sometimes defining the management area is a simple task. In the case of smaller properties, or those which have few weeds, it is often appropriate to regard the property as a single management area. If portions of the property differ greatly in factors such as weed species, topography, soils, elevation or management goals, it may be better to divide the area into separate management units. Management units should reflect the context and use of the property. For instance, the owner of a tract in a rural sub-division may decide to work with adjacent landowners to establish a multi-owner weed management area. Or a manager of a large state park might establish one weed management area for heavily trafficked areas such as roads, trails and campgrounds, and another that encompasses the rest of the park.

There are no hard and fast rules about determining management units. The most important consideration is to use common sense in developing management units which will work best for the property in question. Keep in mind that each unit will need a management plan. For most private landowners, it is probably best to include the entire property in a single management plan. Consider the possibility of working with adjacent landowners to create one or more weed management areas. This can be especially useful for small properties, such as rural subdivisions or ranchettes. A property owners' association may be a good vehicle for organizing neighbors to manage weeds. Weed management units could be individual properties or groups of properties, depending on the particular situation. A coordinated, cooperative effort is always more efficient and effective than piece-meal actions.

## **DELINEATING THE PROPERTY OR MANAGEMENT AREA BOUNDARIES**

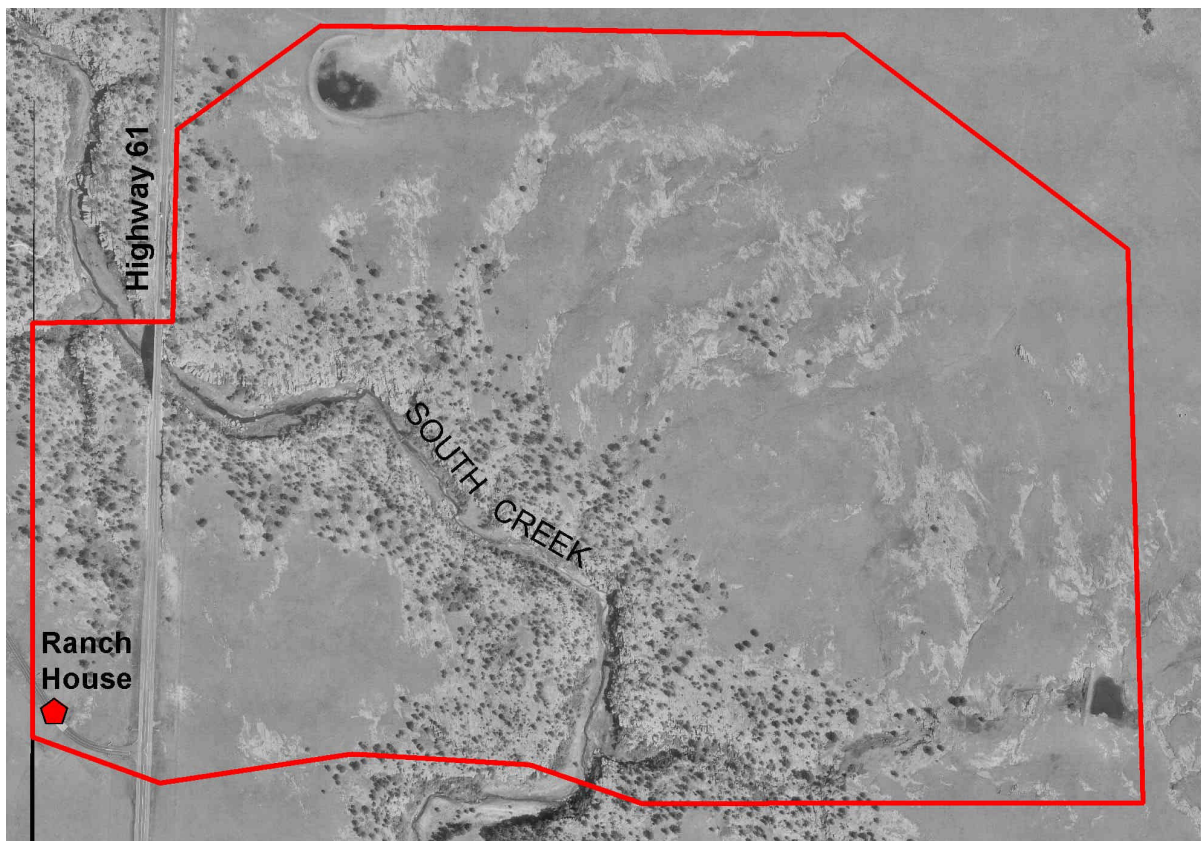
The boundaries of each management unit should be drawn on a map or aerial photograph. No single type of map or photo is the best for all types of planning and weed control activities; select the type which is most appropriate for your situation. Several sheets of transparent plastic or

mylar will also be required later in the mapping process. Mylar is a specially coated plastic which is easy to write on with pencil or pen, and is available through art, office and copy stores.



### SMALL PROPERTIES

For smaller properties (less than a few thousand acres in size), an aerial photograph is probably the best way to show the boundaries of a management unit. Important features such as fence lines, which are not always shown on USGS topographic maps, are usually visible on these photos.



*Aerial photo of hypothetical small ranching property boundaries*

There are three common sources of high-quality black-and-white aerial photographs, and the “aerial photography” of the local phone book may list other sources:

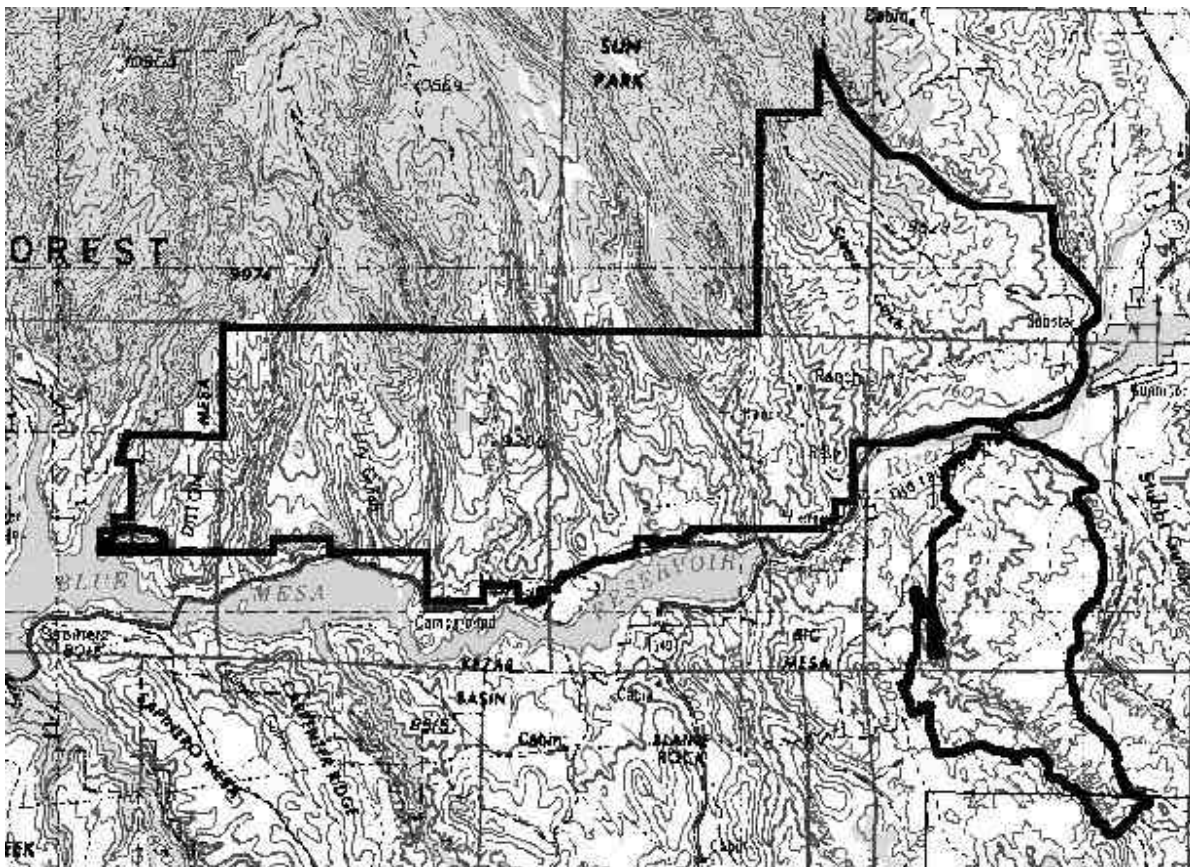
- Published soil surveys. These are the least expensive and often most useful aerial photographs. The local Natural Resources Conservation Service (NRCS) can provide information on the availability of soil surveys in a particular area. The Colorado soil survey list is available at <http://www.statlab.iastate.edu/soils/soildiv/sslists/sslistco.html>, or by calling the State Conservationist’s office in Lakewood at 303-236-2886. These soil surveys are usually free of charge, and contain other valuable information for management planning.

- Local Farm Service Administration offices or county planning departments, typically located in the county seat. The telephone number for the office is listed in the Federal Government section of the local telephone directory under “Agriculture Department.” These offices keep photos which are used by NRCS and Soil Conservation District employees to prepare farm and ranch conservation plans. The photos are available for inspection during regular business hours. Copies of the photos may be ordered from the US Department of Agriculture in Salt Lake City, Utah, <http://www.fsa.usda.gov/dam/APFO/airfoto.htm> (see Appendix 1, page 87). Photos are available in a variety of sizes and scales, and black and white prints normally cost less than \$20.
- The US Forest Service and Bureau of Land Management have aerial photographs of lands which they manage. In many cases adjacent properties are included in these photos. These photos are available for inspection at local USFS and BLM offices, and copies may be ordered from the USDA in Salt Lake City or online from the USGS National Aerial Photography Program Photofinder at [http://edc.usgs.gov/content\\_products.html](http://edc.usgs.gov/content_products.html). Recent photographs from the USFS and BLM are often available in color.



### LARGER PROPERTIES

For larger properties, a map is a good alternative or supplement to an aerial photograph. Several types of maps are available:



*USGS 1:250,000 scale map with land management unit boundary indicated*

- US Geological Survey 7.5 minute topographic maps at a scale of 1:24,000. They cost about \$5 each.
- US Geological Survey County maps. USGS publishes county maps for the entire state at a scale of 1:50,000, and they cost about \$6 each. USGS maps are useful for larger weed management areas. These maps are available at a wide variety of map, outdoor and sport shops or they can also be ordered directly from the US Geological Survey in Denver (see Appendix 1, page 87).
- The Bureau of Land Management publishes maps at a scale of 1:100,000. BLM maps cover the entire state, cost about \$7 per map and are available from map, outdoor, and sporting goods stores.
- The US Forest Service publishes maps of the National Forests, often at a scale of 1:126,720 (1 inch on the map equals 2 miles on the ground). Forest maps cost about \$6 - \$10 depending on the size of the Forest and are available from map, outdoor, and sporting goods stores.

USGS 7.5 minute quadrangle maps are also available in digital format. This format is particularly appealing for public land managers who manage large areas. A private company has digitized and "seamed" together quad maps for Colorado and packaged them in three CD-ROMs. One covers Front Range cities and recreational areas from Ft. Collins to Colorado Springs. One covers central ski areas and surrounding National Forests including Aspen, Vail, Copper, Glenwood Springs, and Steamboat Springs. The third one covers southern Colorado including the San Juan Mountains, Telluride, and Durango. Each CD costs about \$50.00. For ordering information, see Appendix 1, pg. 87.

Although BLM and Forest Service maps show property ownership, this information is often out of date due to land trades or sales by the federal and state agencies. These maps do not show topography and are most useful for larger tracts such as federal or state grazing allotments and leases. Generally, these maps are not appropriate to show individual weed management units.

If your weed management unit is part of a larger property, it is very important to prepare a map or purchase an aerial photograph of the larger land ownership to help you understand the relationship of the smaller weed management unit to the larger property or management area.

- ☒ Prepare a base map or aerial photograph showing the boundaries of the property or management area, as appropriate.

---

## IDENTIFYING RESOURCES ON YOUR PROPERTY

A clear understanding of the resource base of a property is essential to creating a successful weed management plan. Not only will it help to justify the effort and expense of weed control, it will also help ensure that control efforts themselves will not damage natural resources. “Resource base” refers to the significant and valuable natural resources on the property. Examples of natural resources include fertile crop lands, irrigated pasture, productive rangeland, wetlands, streams, riparian areas, old-growth forests, various vegetation types (e.g. shortgrass prairie, shrublands, forests), wildlife winter range, sensitive plant or animal species, and more.

For the purposes of this handbook, the focus is on natural rather than infrastructure resources. Natural resources include land, fish, wildlife, biota (the flora and fauna of a region), air, water, ground water, drinking water supplies, and other such resources. Many landowners already know their natural resources very well. The intent of this exercise is to identify the major resource values of the management area, as an aid to determining management goals and objectives.

For private landowners, mapping the locations of important natural resources will help determine weed infestation priorities. For example, a new weed infestation in the best pasture may be more significant than one in a poor-quality pasture.

### **Examples of natural resources relevant to private landowners:**

- Areas with intact native plant communities
- Areas used by wildlife
- Dry rangeland
- Horse pasture
- Naturally sub-irrigated pasture
- Streams, ponds and wetlands
- Commercial timber
- Irrigated pasture
- Areas that shelter livestock during bad weather

For managers of public lands, the variety and extent of natural resources entrusted to their care poses a special challenge. Weed management policies are subject to public scrutiny, especially where they affect resources which are highly visible to the public, or those which are of concern to special interest groups. The identification and mapping of major natural resources will be helpful in explaining weed management issues to the public.

**Examples of natural resources pertinent to public land managers:**

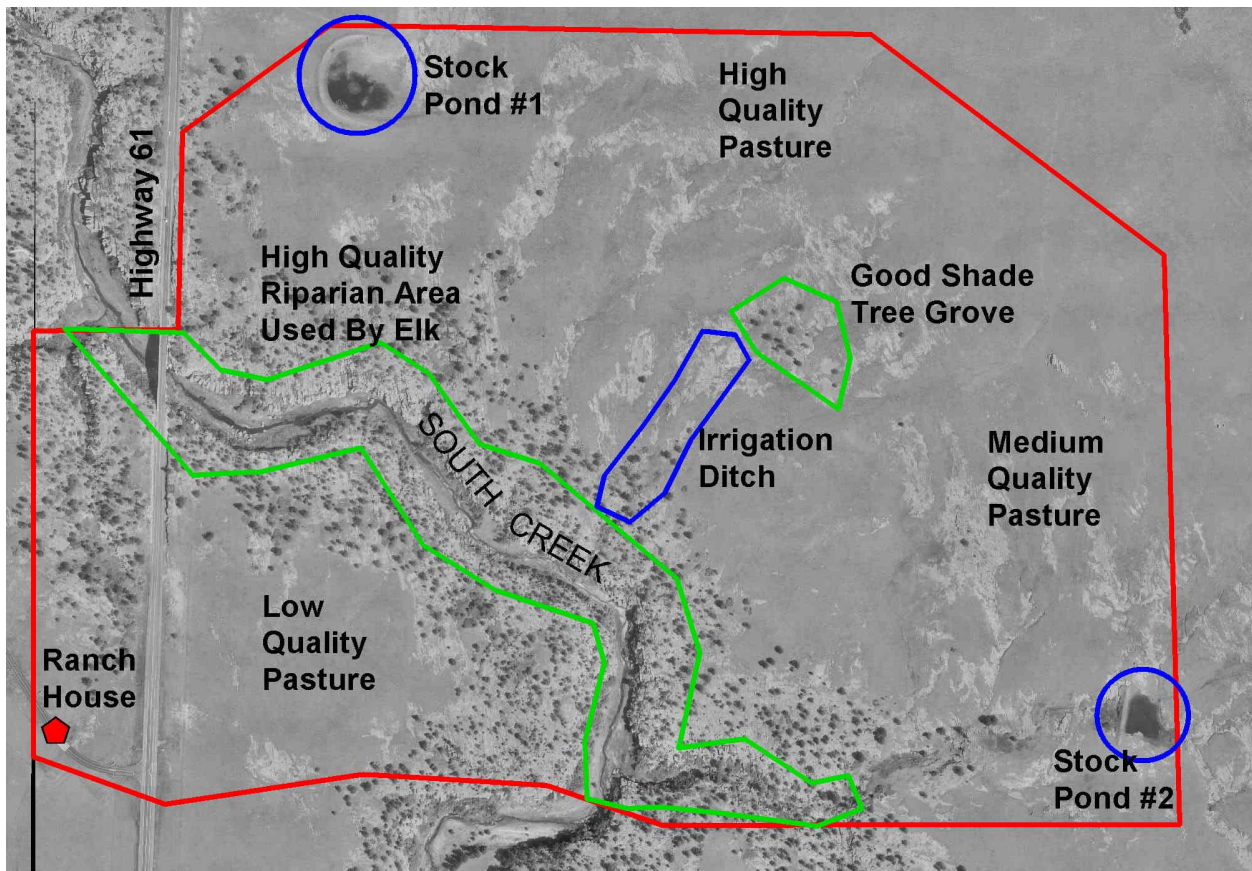
- Streams, ponds, and lakes
- Wetlands and riparian areas
- Wildlife habitat
- Old-growth forests
- Outstanding examples of common plant communities
- Threatened, endangered and sensitive species and plant communities
- Areas of Critical Environmental Concern
- Research Natural Areas
- Wilderness areas
- Developed recreation sites
- Commercial timber and grazing lands
- Administrative sites

Local experts, agency staff and neighbors may be a good source of information about natural resources on your property. Knowledgeable people include county extension agents, county weed supervisors, district wildlife managers, range conservationists, and other government agency scientists. College or university faculty members may also be valuable sources of information. Public land managers should consider contracting with outside entities such as the Colorado Natural Heritage Program at Colorado State University to conduct natural resource inventories of their management areas. Such inventories are commonly conducted at the county level.

**For smaller properties**

Use a layer of transparent plastic or a sheet of mylar taped in place over the base map or photo. Make registration marks to enable the transparent sheet to be repositioned in exactly the same place. Simple registration marks can be made by making a small “+” in each corner of the base map, then placing the transparent sheet on top and making “+” marks on it directly over the marks on the base map or photo.

- ☒ Note the names and locations of the important resources on the property on the transparent overlay.
- ☒ Write a few sentences or paragraphs describing the significance of the natural resources on the property or management area, and enter this information in the appropriate weed management outline.



*Small ranching property with natural resources indicated*



### For larger properties

Because public land managers are often faced with managing large expanses of land, the task of describing and depicting the natural resource base can be much more challenging than for small properties. However, public land managers may also have access to information and resources not available to private landowners.

Public land management agencies may have resource information in digital form in a Geographical Information System (GIS) which can be used to produce color maps of resources and weed infestations. These can be of tremendous help in communicating the magnitude of local weed problems and potential damage from particular infestations to the public. Most public agencies now have some level of GIS capability. Consult staff colleagues and in-house GIS experts about how to use GIS to describe and map natural resources values and weed infestations. The Colorado Natural Diversity Information Source (NDIS) at: <http://ndis.nrel.colostate.edu/> is a good place to start investigating the variety of available GIS data.

In addition, resource inventories and surveys produced by agency staff or outside consultants may be available. Forest plans and resource area plans contain a wealth of natural resource information. It is advisable to summarize the natural resource values of the management area

instead of attempting to discuss them in detail. Reports and other documents can be referenced in the plan for readers who want further information.

- ☒ Note the locations and names of the resources of the management area on a map generated by a GIS. Alternatively, use transparent sheets taped over the base map or aerial photo of the property.
- ☒ Write several paragraphs which summarize the significant natural resources on the management area, and enter this information in the appropriate weed management plan outline.

# III.

## INVENTORYING YOUR PROPERTY OR MANAGEMENT AREA FOR WEEDS

It is imperative to know which weed species are present on your property or management area, and where those weeds are located. This information is critical for deciding which species and infestations are high priorities for management. Conducting a weed inventory is the best way to assemble this information and help insure that management efforts are cost-effective.

The first step in conducting a weed inventory is to make a preliminary list of the weed species that are likely to occur on your property or management area. Consult a county or municipal weed supervisor to learn which weeds are a problem in your area. Obtain the list of weeds that are designated as noxious in your county and which you are legally required to control. See Appendix 2 (page 93) for a list of county weed supervisors. The latest version of this list is also available at [www.ag.state.co.us/dpi/weeds](http://www.ag.state.co.us/dpi/weeds).

☒ List the potential weeds on the property in the table in the weed management plan outline.

### PREPARING FOR FIELD WORK

This handbook contains detailed profiles of many weed species. However, it is not intended to be a weed identification guide. It is a good idea to obtain a reference book with either color pictures or high-quality line drawings of weeds.

- *Troublesome Weeds of the Rocky Mountain West* is a pocket-sized book that has color pictures and brief descriptions of common weeds. Single copies may be available free of charge from your county weed supervisor or for \$3 each from the publisher (Colorado Weed Management Association). This information is also available online at: [http://www.cwma.org/2\\_bad\\_weed.html](http://www.cwma.org/2_bad_weed.html).
- *Weeds of the West*, edited by T.D. Wilson, is another popular reference, available through local bookstores or CSU Extension offices for about \$20. This book has larger color pictures and more extensive descriptions of weed species than the previous booklet. Please note that *Weeds of the West* is oriented toward production agriculture and includes native plants that are not considered noxious weeds in this handbook.
- Individual identification postcards for 60 weed species are available from the Wyoming Weed and Pest Council for \$ 0.10 each (see Appendix 1, page 87). The pictures and information are excerpted from *Weeds of the West*. The cards are easy to carry in the field,

and can be a useful public awareness tool as inexpensive handouts to neighboring landowners.

- *Weeds of Colorado* by R.L. Zimdahl, 1983 includes line drawings of many Colorado noxious weeds. Available from the CSU Cooperative Extension Service, Fort Collins.
- There are also a variety of sources of weed photographs available through the Internet. Although these sites may not include pictures of all of Colorado's noxious weeds, many species are represented. A couple of useful sites are:

Idaho's Noxious Weeds: <http://www.oneplan.state.id.us/pest/nw00.htm>

Weed Science Society of America Photo Herbarium: <http://ext.agn.uiuc.edu/wssa/>

Use one or more of these references as an aid to identifying weeds correctly in the field. A 10x hand lens is helpful for seeing small plant parts. These lenses are available from book and hobby stores or from mail order catalogues (see Appendix 1, page 87). If you will need to collect plants for later identification, see Appendix 13 (page 337) for suggestions about making a simple plant press and helpful hints for collecting plants.

## SEARCHING FOR WEEDS

As with most plants, weeds are easiest to find when they are flowering. Because all weed species do not flower at the same time, a weed inventory will be most complete if it involves searching for weeds several times during the growing season. Conduct field inventories when the most troublesome weeds in your area are likely to be most visible. At lower elevations, early May is a good time to begin searching, since early flowering species like blue mustard and hoary cress will usually be flowering by then. At higher elevations, early to mid July is a good time to begin a weed inventory. Always consult your county weed supervisor for advice on the best times for weed identification and inventory in your area, and ask for locations where you can easily find and learn to identify common weeds in your area.



### For smaller properties

Formulating a strategy for weed inventory depends on the size and topography of the property, and on the weeds you expect to find. Properties up to about 1000 acres in size can usually be sampled fairly intensively, especially if they are flat, by walking or riding a 4-wheeler or horse. If you intend to walk or ride the entire property, use a structured approach such as traveling along imaginary lines (transects) that extend the length of the property. Space the transects in such a way as to ensure that all of the terrain can be seen. Factors such as height and density of trees, shrubs and grasses, the presence of rocks and cliffs, and the prominence of the weeds will determine the distance between adjacent transects. Some weeds such as leafy spurge and purple loosestrife are easy to spot when they are flowering; others such as puncture vine and sulfur cinquefoil are inconspicuous even in flower.

Transects may also be placed along linear features such as roads, trails, ditches or streams. Often these features are especially prone to disturbance and susceptible to weed

establishment. Check other disturbance-prone sites such as livestock handling facilities, paths, stock ponds, erosion areas, parking areas and areas around gates.

Suppose that your property consists of one section (640 acres) and that you are most interested in locating these relatively visible weeds: spotted knapweed, Dalmatian toadflax and leafy spurge. These species are most visible when in flower. Dalmatian toadflax can bloom twice during the growing season if rainfall is abundant, so you might conduct a second field inventory if you find a lot of Dalmatian toadflax during the first inventory.

You could walk or ride transects that are 300 feet apart running the length of the property. This would require 17 transects or 17 miles of travel. If you use a 4-wheeler or a horse, you could inventory the property in one day. The increased visibility from atop a horse would be a plus. Such an inventory would require two days if you walked. Periodically marking your path with surveyor's tape or pin flags will help you keep subsequent transects oriented properly.

Carry a weed identification book and a copy of the map or photograph of the property. Maps and photos can easily be ruined in the field, so it is best to carry a copy rather than the original. County weed supervisors, extension agents, range conservationists or knowledgeable neighbors may be willing to visit the property and offer advice on getting started. If you are uncertain of the identification of any weed species, write a brief description of it, or collect and press a specimen for later identification (see Appendix 13, page 337). Be sure to record the date and location of the collection of each specimen on the paper used for pressing; otherwise you are likely to forget where the plants were collected. Your county weed supervisor or extension agent may be able to identify weed specimens, or refer you to someone else who can do so. Faculty members or graduate students at universities and colleges, and herbarium staff members are often willing to identify pressed plant specimens. Knowledgeable volunteers affiliated with local land trusts or with the Colorado Native Plant Society are another possibility.

For each weed infestation encountered on the property record the species name, location and severity of infestation. Use the copy of the map to sketch the location and extent of each occurrence. The goal is to record enough information to complete a detailed weed map as described below.

- ☒ Fill in the table in the weed management plan outline with the names of the weed species found on the property or management area.



### For larger properties

While the above inventory strategy works well for small properties, it is not often feasible for large areas such as national forests and other public lands, public land grazing allotments, state school land leases, tribal lands or large private ranches. Instead, develop a short list of the weed species on which inventory efforts will focus, including those species on the local county noxious weed list. Check with the county weed supervisor and neighboring property owners/managers to find out where noxious species are on your boundaries and which ones

you are most likely to find. Areas which are subject to significant disturbance or are heavily trafficked are especially prone to weed infestation. Such areas include roadsides, stock driveways, trails, parking and camping areas, recently burned areas, larger streams (particularly after floods), irrigation ditches, and livestock handling facilities.

Inventories on large properties should focus on:

- Weed species which will be hardest to control if not managed immediately.
- Locations which are most likely to be colonized by weeds.
- Highest value natural resource areas.

Plan a systematic survey of as much of the property as possible, using the above criteria to identify and prioritize areas to be searched. Public land managers should also enlist the help of lessees and grazing permittees; information about the location of weed infestations is important to both parties. Members of the general public can also be encouraged to report weed infestations, and are more likely to do so if managers exhibit a serious commitment to managing weeds.

Record the species name, location and severity of each weed infestation encountered on the property. Use copies of the property map(s) to sketch the location and extent of each occurrence. If Global Positioning System (GPS) units are practical and available, they can be used to record weed locations (see below). If you are uncertain of the identification of any weed species, write a brief description of it, or collect and press a specimen for later identification (see Appendix 13, page 337). Be sure to record the date and location of the collection of each specimen on the paper used for pressing; otherwise you are likely to forget where the plants were collected.

- ☒ Fill in the table in your weed management plan outline with the names of the weed species found on the property or management area.

## MAPPING WEED INFESTATIONS

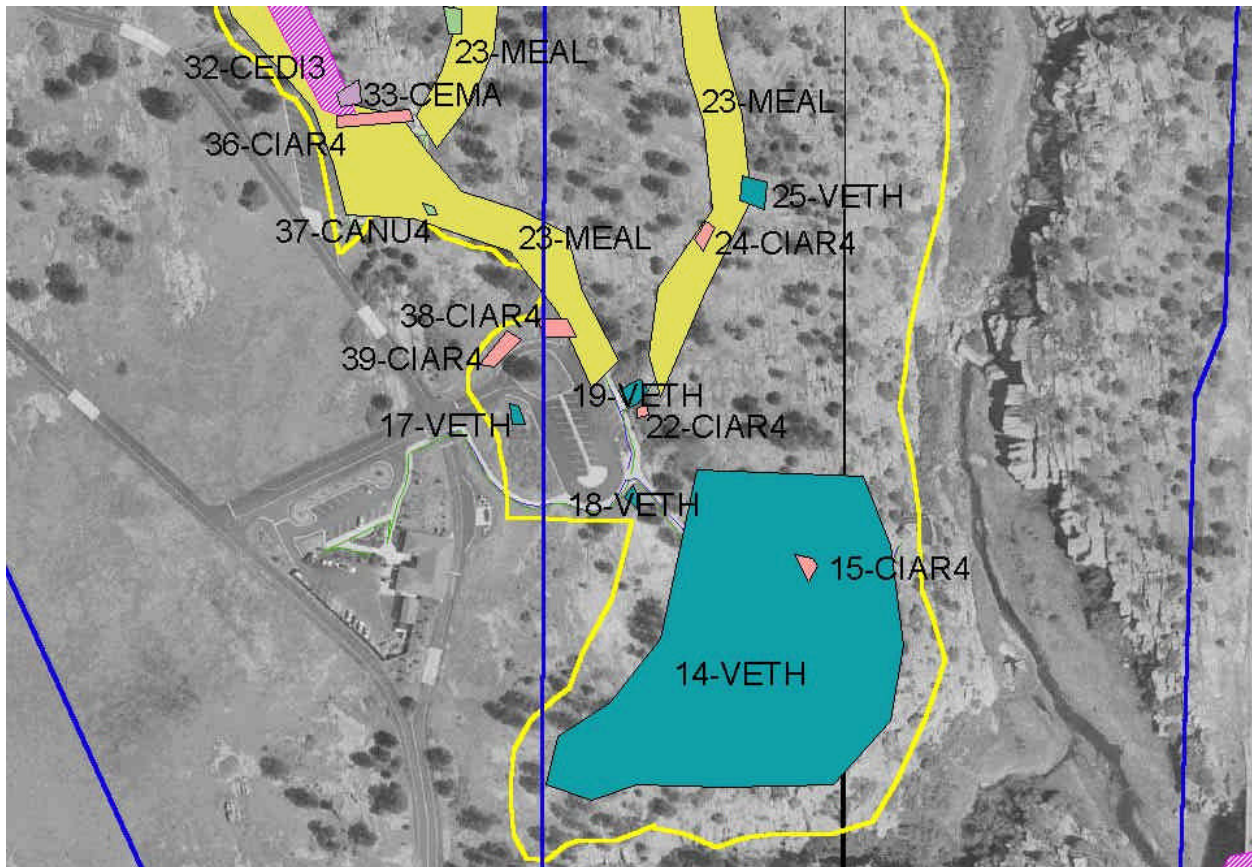
A completed weed map should show the locations and general extent of weed infestations on the property. Having a written record of the size and location of each weed patch will make your weed management plan more efficient. The map will also be used to evaluate the effectiveness of weed control actions.



### **For smaller properties**

Use clean sheets of mylar or transparent plastic taped over the base map or photograph to map each weed species. Depending on the number of infestations, several species may be combined on one sheet. Write the name of the property and the weed species on each sheet. Make a registration mark (“+”) in each corner of the overlay sheet matching the same mark on the base map or photograph to facilitate repositioning the sheet in the same place later.

Weed infestations vary greatly in size. Use the methods and symbols described below, or a similar system, to denote each infestation on the overlay sheet. Label each infestation if there is more than a single species on each sheet. Abbreviated names may be used to save time and space. Two standardized systems are the 5-letter “Bayer” code from the Weed Science Society of America, and the USDA alphanumeric code. See Appendix 1 (page 87) for further information on obtaining lists of these codes. If you use abbreviations, write them next to the full name of the plant in the table in the weed management plan.



Example of weed mapping on aerial photo

The following system of quantifying weed infestations is modeled on the mapping approach developed by the Montana State University Extension service:

- Draw a line around the boundaries of infestations that are larger than five acres in size.
- A square denotes infestations from 1- 5 acres.
- A triangle denotes infestations from 0.1 – 1 acre.
- An “x” marks infestations less than 0.1 acre.
- A solid line can be used to demarcate narrow infestations along linear features such as roads, streams or lake edges.

One variation for using colored markers is to have separate maps for each species and then use the different colors (or different shades of the same color) to represent different density or intensity levels of infestation. This allows you to make comparisons from year to year and to see what impact management actions are having on the species.

By way of comparison, 1 acre is 209 feet by 209 feet or about the size of one football field. On a 1:24,000 USGS map, 1 acre is represented by a square that is a little less than 1/8 inch by 1/8 inch or a rectangle about 2.5 mm x 3 mm. Five acres is about the size of five football fields. On a 1:24,000 USGS map, 5 acres is represented by a square that is about 1/4 inch by 1/4 inch or about 6 mm by 6 mm.

Use colored pencils or felt-tipped markers to create color-coded maps, using the same color consistently for the same weed species. Color-coded maps make it easier to visualize the number and locations of weed infestations, and transparent overlays allow infestations to be seen in relation to one another and to the resource base of the property.

- ☒ Map the locations of weed infestations on your property or management area on copies of your base map or aerial photographs or on plastic sheets that overlie the base map or photograph. Use appropriate symbols for and label the infestations with the weed species name(s).



### For larger properties

Public land managers and owners of large private tracts face special challenges in mapping large land areas. There are two basic approaches in mapping weeds on large areas.

In one alternative, the simple low-tech methods of hand-mapping described above can be adapted for use on larger properties. Selecting the appropriate base maps involves a trade-off between map accuracy and the number of maps required. USGS 7.5 minute quadrangle topographic maps are the “industry standard” for hand mapping. However, mapping weeds for an entire National Forest Ranger District or BLM Resource Area would require many quadrangles, making it inconvenient to transport and organize weed maps. Maps at a smaller scale (i.e. showing less detail) may make it difficult to locate infestations with sufficient accuracy to be useful in management planning. Use the most detailed map practical for your particular circumstance. Hand-drawn maps can also be digitized and imported into a Geographic Information System (GIS) and used to produce maps of weed infestations.

As another alternative, Global Positioning System (GPS) units make spatially-referenced digital weed location data available for use in GIS preparation of weed infestation maps. Such units are especially useful for surveying weeds along roads. These handheld or backpack instruments use signals from satellites in orbit above the Earth to determine the precise position of the GPS unit. Although a period of training is required to learn the proper use of a GPS unit, it may be a cost-effective tool for inventorying larger management areas with many noxious weed species. The perimeter of a weed infestation can be mapped by collecting position data for various points while walking around the edge of the patch. Or, an infestation may be mapped as a single point or a line. Data from a GPS unit can be downloaded to a GIS to create one or more maps of weed infestations. GPS units have varying levels of precision, which means that the location of a weed infestation will not be measured exactly. This introduces some error into comparisons of the locations and sizes of weed infestations over time. Detailed field notes from the GPS operator can help reduce

---

these errors in interpretation. See Appendix 1 (page 87) for more information about GPS products.

Montana State University Extension has produced two publications on weed mapping, including the use of GPS units. The *Weed Mapping Handbook* explains the Montana Weed Survey and Mapping System in great detail, and is recommended reading for anyone contemplating using a GPS unit for mapping weeds. The bulletin *Mapping Noxious Weeds in Montana* is a less detailed and more readable discussion of weed mapping. Both publications are available via Internet at: <http://www.montana.edu/places/mtweeds>. The site also includes a GPS laboratory with slide shows explaining beginning and advanced GPS theory (<http://www.montana.edu/places/gps/index.html>). Colorado is currently developing a standardized weed mapping protocol to facilitate the sharing of information. It will likely be similar to the approach developed in Montana. More details are available from the State Weed Coordinator in the Colorado Department of Agriculture (303-239-4182).

- ☒ Map the locations of weed infestations on the property or management area using the appropriate mix of tools for the situation.

"I think the variety of public opinions surrounding noxious weed management is no different from other natural resource issues like wildlife management, forest management, etc. There are a lot of emotions directed at the land manager over what they are or are not doing - falling under scrutiny. I keep in mind that everyone has a right to their own opinion - which will certainly come into play during any public hearing process. If I look at all the individual control tools that we use in our Integrated Weed Management Program, I can also think of a group or individuals who will commonly oppose a single tool - whether it is herbicide use, grazing, or whatever. It is the land manager's job to take into account all opinions and help people understand the scope in which the various tools are being used with the total integrated program. There are ways that any tool can be misused or used to a great benefit. It is our responsibility to be as knowledgeable as we can, to use control tools as wisely as possible for the protection of wildland ecosystems. This is not a situation where we can just "let nature take its course". We humans brought the problems here relatively recently, and it is our responsibility as land managers to use all the appropriate tools to contain and control the spread of weeds."

Cindy Owsley  
Boulder County Parks and Open Space

## IV.

# LAND MANAGEMENT GOALS AND WEED MANAGEMENT OBJECTIVES

Successful people are almost always goal-oriented. In general, setting goals before beginning a task helps ensure that objectives are achieved. This principle holds true for weed management planning as well. If you have not already established land management goals for your property or land management area you should do so before moving on to the next step in the planning process. Specific weed management objectives based on management goals and on the information gathered during a weed inventory will help determine weed management priorities and influence the selection of management actions.

Setting goals and objectives ensures that you are engaging in weed management to protect your resources and not just to kill weeds. As an integral part of the planning process presented in this handbook, management goals and objectives are beneficial because they:

- Make more efficient use of limited resources.
- Focus time and money on important natural resources.
- Enable selection of the most important weed species and infestations to control.
- Provide specific criteria for evaluating the effectiveness of control actions.
- Focus public debate about weed management on management goals (where people are more likely to find common ground) rather than solely on control actions (where people are less likely to agree).
- Increase public accountability.

## MANAGEMENT GOALS

Management goals are brief statements that describe the conditions you wish to create or maintain in the management area, not just things related to weeds. Goals usually focus on human values, natural resources and financial resources. Use the examples below as an aid to developing your own goals.

The most important thing about writing goal statements is simply to do it. An imperfect goal statement is better than no goal at all. Goals can easily be revised and changed as your knowledge of the property increases and personal desires change. Include other people who have an interest in the property in the goal writing process. For instance, spouses, children, parents, other relatives, neighbors, friends, ranch employees, agency staff, and the local extension agent may all have valuable input. The assumption is that several people working

together may be able to produce a better goal statement than one person working alone. Including other people in the goal setting process often has the effect of increasing their level of involvement in implementing the weed management plan. People are usually more willing to participate in a plan if they have a say in its preparation.



Examples of management goals that may pertain to private landowners. These statements illustrate aspects of human values, natural resources and money that you may wish to incorporate into your goals.

1. Maintain a viable working ranch so our children will be able to continue the family ranch tradition.
2. Build a home that will allow us to enjoy our rural setting on a daily basis.
3. Be a good neighbor with surrounding landowners.
4. Generate enough income from the ranch to support our family.
5. Increase the productive capacity of the land by increasing solar energy capture by perennial plants, increasing the infiltration of water in to the soil and increasing nutrient cycling.
6. Maintain a diverse landscape of forest, shrubland and grassland communities.
7. Improve the condition of the riparian areas and wetlands along Spring Creek.
8. Contribute to the protection of the local watershed.
9. Preserve habitat for native plants and animals.



Examples of management goals that may pertain to public land managers. These statements illustrate aspects of human values, natural resources and public concerns that you may wish to incorporate into your goals.

1. Provide opportunities for public education and recreation.
2. Identify and protect cultural and historic resources.
3. Support the local economy with a timber sale program and a livestock grazing program.
4. Be a good neighbor with individuals who own private in-holdings in the Forest.
5. Maintain a landscape of diverse forest, shrubland and grassland communities.
6. Maintain populations of globally rare plants and animals and examples of globally rare plant communities.
7. Increase overall range condition for the Resource Area, focusing on riparian areas.

☒ Write management goals and record them in your weed management plan outline.

## WEED MANAGEMENT OBJECTIVES

Objectives are statements which are specific, measurable, achievable, have a deadline and are location specific. Objectives provide a link between very general goal statements and specific action steps. Objectives should also be written to comply with local and regional regulations regarding noxious weeds. And, although your goals and objectives will certainly be influenced by these legal requirements to manage noxious weeds on your property, you may also want to control weeds that are not yet on your county list.



Examples of management objectives that may be helpful for private landowners. These statements are based on the sample goals for private landowners in the box above, and are numbered accordingly.

3.
  - a) Eliminate noxious weeds from the 1-acre area that surrounds our home within two years.
  - b) Reduce the abundance of Dalmatian toadflax on the property by one-half over the next five years.
  - c) Reduce the density of houndstongue in the North Horse Pasture to less than one plant per 100 square feet within three years.
4.
  - a) Over the next two years, reduce by 95% the number of Canada thistle stems producing seed along the Braley Ditch.
  - b) Work with the neighbors to prevent any new infestations of noxious weeds from establishing on our neighbors' property within 100 feet of our property over the next five years.
  - c) Work with the local elementary school teachers to organize and host one field trip to the ranch each year to discuss our weed control program.
6.
  - a) Over the next five years, eradicate any new infestations of noxious weeds within one year of their discovery on our property.
  - b) Limit the existing infestation of diffuse knapweed to the South 40 Pasture starting this year and continuing over the next five years.



Examples of management objectives for public land managers. These statements are based on the sample goals for public land managers in the box above.

1. a) Reduce the abundance of houndstongue within 100 feet of all trailheads and parking areas on the Tall Timbers Ranger District of the National Forest to less than one flowering plant per 100 square feet of ground surface within three years.  
b) Kill and remove all tamarisk plants over ½ inches in basal diameter from the Beaver Creek Recreation Site within two years.  
c) Eliminate any seed production from all noxious weeds within all Forest campgrounds each year for the next five years.
2. Eliminate production of noxious weed seeds within 100 feet of the Cunningham Cabin historic site each year over the next five years.
3. Reduce the overall canopy cover of the three highest priority noxious weeds on the Resource Area by 5 percentage points each year for the next ten years.
4. a) Prevent any infestations of weeds from crossing from State Park ground on to our neighbor's property over the next five years.  
b) Organize and lead three public field trips each year for the next five years oriented around the theme of weeds and weed management.
6. Prevent the establishment of leafy spurge on the Franklin allotment over the next ten years.
7. Eliminate any noxious weeds that appear within 100 feet of the population of rare penstemon in the Stony Ridge Research Natural Area each year for the next ten years.
8. Within five years, reduce the abundance of Russian knapweed and perennial pepperweed along French Creek in the French Creek Allotment by 75% over what it is currently.

## V.

# PRIORITIES FOR WEED MANAGEMENT

It is impossible for the vast majority of landowners and land managers to control every weed, noxious or otherwise that occurs on their property or management area. Therefore it makes sense to focus control efforts on those weed species which have the greatest impact on the resource base, and those which become more difficult to control if action is delayed. Weed management priorities can be established by determining which are 1) the priority weed species and 2) the priority weed infestations, in light of the established weed management objectives.

### PRIORITY WEED SPECIES

Some landowners may have only one or two noxious weed species on their property. In this case it may be feasible to control all of the noxious weeds. At the other extreme, some landowners and managers may have so many noxious weeds that the task of controlling them seems overwhelming. These landowners and managers will not be able to control all the weeds on their property in the short term. In cases where a complete control program would require more time and money than is available or prudent to spend, landowners and managers must decide which weed species are most important to control.

Fortunately, only a small proportion of weed species cause significant resource damage. For example, Rocky Mountain National Park supports about 1000 species of vascular plants, including 104 nonnative species. The park is managing 24 of these nonnatives, and only 12 of them are considered to be serious problems (J. Connor, personal communication). The situation is similar in Great Smoky Mountains National Park, where 400 of 1500 plant species are nonnatives. However, only 10 species appear to be spreading or pose a threat to park resources (Hiebert 1997).

A priority list of weed species can be based on the actual or potential impact of the weed species on management goals and on the feasibility of weed control. The ranking system explained below is designed to identify which weeds are the highest priority for control on a property. This approach has been used successfully in a number of areas (including Rocky Mountain National Park) to prioritize weeds for management. However, you should also use your knowledge of local conditions in assigning and interpreting weed rankings.

## RANKING WEED SPECIES

If a weed inventory shows that a large number of weed species are present on a property, the prospect of ranking so many species may be discouraging. In such cases, consulting the county weed supervisor may allow you to eliminate from consideration some weeds which he/she thinks are unlikely to cause significant damage to your resource base, and which you are not required by law to manage. The decision not to control a particular weed species must be made with care. Here are two methods of weed ranking:

### A simple method

A list of priority weed species can be developed by working with the county weed supervisor. Many private landowners may opt for this simple approach. A county weed supervisor can use the list of weeds found on your property and his/her knowledge of the local area to advise you on which weeds pose the greatest threat and which are most easily controlled through immediate action. These species are the highest priority weeds. Other weed species on the property can be assigned to medium and low priority categories.

*In general, weed species which are rare on the property or management area and those that have small populations should be eradicated while large populations of common weed species should be contained or suppressed.*

### B LIST

These are the top ten priority weeds for Colorado, as listed in the Colorado Weed Management Act. Overall, these species are the most widespread and cause the greatest economic impact in the state. These species will be candidates for your priority weed species list. These species are marked with in the species profiles in Appendix 4.

Canada thistle	Leafy spurge
Diffuse knapweed	Musk thistle
Field bindweed	Russian knapweed
Hoary cress (small or low whitetop)	Spotted knapweed
Jointed goatgrass	Yellow toadflax

- ☒ List the high priority weed species for the property in the table of the weed management plan outline.
- ☒ Re-visit your weed management objectives to determine if they need to be revised in light of this weed prioritization.

## A more complex and thorough method

A formal weed ranking system is a more complex way to prioritize weed species. Public land managers may choose this method because it provides a less biased and more objective way to identify which weeds should be controlled most vigorously. Weed management plans and actions can be controversial; a formal ranking system can help land managers explain to the public why certain species will be controlled, and others will not, and justify the choice of control measures. In addition, the results of a formal ranking system may be more persuasive than personal opinion in convincing supervisors that certain weeds are truly a problem and that funds must be secured to manage them.

The weed ranking system recommended here is the Alien Plants Ranking System (Version 5.0). The ranking form is found in Appendix 6 (page 301). This system is also available via Internet at <http://www.ripon.edu/faculty/beresk/aliens/>. The prototype of this system was developed by Ron Hiebert of the National Park Service and Jim Stubbendieck of the University of Nebraska. The procedure has been further developed and modified for use in a number of locations in the United States. It has been tested in a variety of National Park Service units, including Rocky Mountain National Park, Indiana Dunes National Lakeshore, Olympic National Park, and six short-, mid- and tallgrass prairies. This approach has also been used by the state of Minnesota to establish weed control priorities. The ranking system can be applied to many types of lands including rangeland used for livestock grazing.

Each species is ranked separately in the Alien Plants Ranking System. Fill out one form for each species that is being considered for control, using copies of the original form. Default answers to many of the questions are provided in a preliminary draft Answers Table also found in Appendix 6. If these standard responses seem inappropriate for your area, you can change them to better suit local conditions. The letter given in the table corresponds to the point total shown next to it on the form. The brackets at the right side show the subtotals from impact, pest and control weights that make up the total score.

Answer all questions for each species, then add up the points from questions 1-17 for the total “significance of impact” score, and the points for questions 18-24 for the total “difficulty of control” score. Transfer these two scores for each weed species to the “Prioritized List of Weed Species” which is included in the appropriate Weed Management Plan Outline in Appendix 3 (page 95). The weed species with the highest impact scores *and* the highest difficulty of control scores are the highest priority weeds for control on your management area. You may also assign medium and low priorities to the other weed species, based on their scores.

The following table shows the results of the Alien Plants Ranking System for a small and very weedy tract that will be added to an urban natural area in a Colorado metropolitan area.


In order to visualize the scores of the weed species in relation to one another, prepare a graph that shows the significance of impact and feasibility of control, as depicted in the figure below. Each weed species is represented by a single dot on the graph, and the dot is located

## Alien Plants Ranking System Results

Alien plants found on Natural Area - name and 2 letter code												
Ranking System Criteria	Canada thistle CT	Cheat-grass CG	Dalmatian toadflax DT	Diffuse knapweed DK	Field bindweed FB	Perennial pepperweed PP	Musk thistle MT	Puncturevine PV	Russian thistle RT	Scotch thistle ST	Summer cypress SC	Tansy mustard TM
<i>I. Significance of Threat or Impact (Site Characteristics)</i>												
1. Distribution relative to disturbance regime	5	0	5	2	5	1	1	0	0	1	0	1
2. Areal extent of populations (percent or acres)	1	3	1	2	3	1	1	1	2	2	2	1
3. Numerical dominance of species within a community	2	3	1	2	3	1	2	2	2	2	2	1
4. Association with native community	3	0	3	3	3	3	3	0	3	0	3	0
5. Hybridization with native species	0	0	0	0	0	0	0	0	0	3	0	0
6. Degree of threat and impact	2	2	5	2	2	2	5	1	1	2	1	1
7. Effects on management goals	5	5	5	5	5	5	5	3	5	5	5	3
<i>II. Innate Ability of a Plant Species to be a Pest (Species Characteristics)</i>												
8. Mode of reproduction	4	2	4	2	4	4	2	2	2	2	2	2
9. Vegetative reproduction	4	0	2	0	2	2	0	0	0	0	0	0
10. Frequency of sexual reproduction	5	5	5	5	5	5	3	5	5	3	5	5
11. Number of seeds per plant	5	5	5	5	3	5	5	3	5	5	5	3
12. Dispersal ability	5	5	0	5	0	0	0	5	5	5	0	0
13. Germination requirements	2	2	2	2	2	2	2	0	0	2	0	2
14. Seed banks	3	3	5	3	5	5	3	3	3	5	3	5
15. Competitive ability	4	2	4	4	4	4	2	0	2	2	2	2
16. Ecological effects	4	8	4	7	4	7	3	0	4	3	4	0
17. Known level of impact in natural areas	5	5	5	10	5	5	5	3	3	5	3	3
Subtotal of points (questions 1-17)	59	50	56	59	55	52	42	28	42	47	37	29
<i>III. Difficulty of Control</i>												
18. Likelihood of successful control	3	6	3	10	6	3	3	0	3	3	3	3
19. Saturation of surrounding region	3	5	1	3	3	3	3	1	3	1	3	5
20. Effectiveness of community management	10	5	10	10	10	5	10	0	0	5	0	5
21. Vegetative regeneration	5	0	5	0	5	10	0	0	0	0	0	0
22. Biological control	10	10	10	10	10	10	10	10	10	10	10	10
23. Side effects of control measures	3	3	0	3	5	3	3	0	0	3	0	0
24. Extra points from questions 2, 3, 14	7	13	7	8	15	7	5	5	8	10	8	7
Subtotal of points (questions 18-24)	41	42	36	44	54	41	34	16	24	32	24	30


at the intersection of the weed's score for significance of impact and the weed's score for feasibility of control. In general, species with high impacts will also be more difficult to control, and there will be an obvious positive relationship in the pattern of dots on the graph (see page 32). The highest priority species will be higher on the graph (because infestations of these species are more difficult to control, particularly as time passes), and further towards the right side of the graph (because these species have higher impacts).

## LIST C

The following weed species are included in List C of the Colorado Noxious Weed Act. These weeds are not yet present in most parts of Colorado, and they are not yet causing widespread economic damage. However, they cause huge problems elsewhere and should be eradicated immediately if possible but at least controlled if they appear on your property or management area. New infestations of these species should be reported to the county weed supervisor. These species are marked with  in the species profiles.

African rue  
Black knapweed  
Camelthorn  
Coast tarweed  
Cypress spurge  
Dyer's woad  
Myrtle spurge

Orange hawkweed  
Rush skeletonweed  
Scentless chamomile  
Squarrose knapweed  
Sulfur cinquefoil  
Yellow starthistle

-  List the high-priority weed species for your management area on the table in your weed management plan outline.

## HIGH-PRIORITY WEED INFESTATIONS

After you have prioritized the weed species to be controlled, the next step is to determine which infestations have the highest priority. The ranking of an infestation will depend on its location and extent. The general rule of thumb is to **attack isolated patches of the highest priority weed species first**. There are two reasons to adopt this strategy: 1) increased efficiency of control efforts and 2) psychological reward. Weeds spread from existing infestations. To reduce the spread of weeds, it makes sense to limit the number of new infestations. Such infestations are typically small, and are easily controlled because they have less well developed root systems, less stored food reserves in roots and rhizomes, and a smaller seed bank in the soil. Controlling isolated patches also gives a landowner or manager a sense of accomplishment, providing the motivation to persist in weed control efforts. High efficiency means gaining control of a weed species problem with a minimum of effort (Neill 1997).

The following categories of infestations should be highest priority:

- **Small, isolated infestations.**

These infestations are usually high priorities, even for species that do not pose the greatest impact to the property's resource base. Consider eradicating all weed infestations that are under 0.1 acre in size (equivalent to a circle with a diameter of 75 feet or a rectangle that is 100 feet long and 44 feet wide). Note that high priority would not apply to a small patch of weeds that is located immediately adjacent to a larger patch of the same weed species; this patch would be a low priority for control.

- **Patches of the highest priority weed species and that, if left alone, would soon be uncontrollable.**

These weed species often have high impact scores and low feasibility of control scores. However, control may be relatively easy if small, new infestations are managed aggressively. For example, if leafy spurge appears on your property, you would immediately control it because it would likely spread rapidly if you ignored it. Large infestations of leafy spurge are very difficult to control.

- **Roadsides, parking areas, trails, ditches and streams.**

Weed infestations in these areas are high priorities for control because they experience frequent disturbance, which creates favorable habitat for weed establishment, and because vehicles and water are two of the most common agents for spreading weeds. Infestations of new weed species may appear first in disturbed sites such as road edges, ditch banks and stream banks. Vehicles travelling along roads and trails can spread weed seeds to other areas. For example, a vehicle that runs over a diffuse knapweed stem can carry the broken stem under the vehicle, spreading seeds into new areas. Similarly, water flowing in irrigation ditches can carry seeds of Canada thistle for many miles. Thus, infestations of Canada thistle that occur along ditches and streams might be higher priority for control than those that grow in more isolated situations. Control along ditches might focus on reducing seed production rather than reducing the size of the thistle patches. Also consider infestations from which weed seeds could blow or be transported by livestock into high-value areas. Other high priority infestations include developed sites such as campgrounds, trailheads, visitor centers, and other developed recreation facilities.

## **LOW-PRIORITY WEED INFESTATIONS**

Large infestations of low-priority weed species, especially species which are easy to control even if left unmanaged, are low priority for control. In such cases it is better to direct control efforts toward limiting the rate of spread into new areas instead of attempting to eradicate the existing population.

---

Large infestations of high-priority weed species may be low priorities for control if they present an exceptionally large weed management challenge. For example, downy brome (cheatgrass) is now very common in grasslands, particularly in areas such as hillsides which are subject to soil movement. Controlling cheatgrass in such situations may not be worth the effort, since ongoing disturbance on hillsides continually creates new opportunities for cheatgrass colonization. The goal of prioritization is to direct limited resources toward those weed control actions which are likely to have the greatest effect in meeting your land management goals and objectives.

- ☒ Identify the locations of the highest priority weed infestations, and note them on a copy of your base map, on one or more overlay sheets, or by using a GIS.

## Attack Your Weeds Like a Wildfire

If you want to concentrate your efforts where they will be most effective, consider this central principle of weed management:

*Small infestations can be eradicated, large infestations can only be controlled. Our usual approach is to attack large areas of weeds first. Most of our resources go to this cause while we ignore small isolated patches. The small patches are not causing any harm now, so we feel they can be ignored temporarily. Before we know it, the small patches have spread, and we are left with more large weed problems. To be effective, we must reverse our priorities and eradicate all small occurrences as quickly as possible.*

Steven Dewey of the Utah State Extension Service (and others) often compare weed management to fighting wildfires. Notice the similarities as you attack your weed problems by following the four steps below.

Fire:	Weeds:
<b>1. Build a fireline</b>	
One of the first actions taken when fighting a large wildfire is to build a fire line to contain the outbreak within a certain boundary.	Rather than a line on the ground, draw a line on a map delineating the current extent of large weed infestations. Commit to containing the infestation within this boundary.
<b>2. Eliminate spotfires</b>	
Any fire that jumps the fireline has top priority and is eliminated as quickly as possible before it has the chance to spread. If allowed to spread, the results can be disastrous: fire fighters may be caught between two outbreaks, two large fires will have to be fought rather than one, and many more resources will be needed.	When weeds escape from the boundary you have drawn, they should become top priority. Think of small isolated occurrences as back country spotfires. If they are located early and attacked aggressively they can be eradicated before they spread; if ignored they will likely become so large they may never be eliminated entirely.
<b>3. Protect critical areas</b>	
Critical areas include places where people or structures are located.	Critical areas include pristine natural sites, critical wildlife habitat, productive rangelands, and rare plant and animal habitat.
<b>4. Control the main outbreak.</b>	
Often an expensive investment in resources is required. Even with massive control efforts, large fires often are not stopped until the weather changes and rain or snow stops the fire.	Large infestations require long-term control efforts. Even with years of effort, these occurrences may never be completely eliminated. Unfortunately their seed banks may be huge, and their natural controls are rarely available. They may require some level of control forever.

## VI.

# WEED MANAGEMENT TECHNIQUES

The need to take action to control weeds should be self-evident. All the planning in the world is worthless unless it is followed by action. A variety of specific weed management actions are presented below. As you consider the possibility of employing any of these actions to control noxious weeds, remember two key points:

1. An abundance of weeds is often symptomatic of certain environmental conditions. It is important to understand and deal with the underlying causes of weed infestation, and to take steps to counter them. If the factors permitting weed establishment and expansion are not addressed, weed problems will continue indefinitely.
2. A single control technique is rarely sufficient to control a particular weed species. The best results in weed control are usually obtained by combining different control methods in a coordinated effort. This strategy is known as Integrated Weed Management, and is the primary focus of this handbook.

Weed management actions seek to achieve various levels of control. They are listed below in order of decreasing degree of control:

- Eradication, where a population of a weed species (including seeds) is completely eliminated.
- Killing an entire population of plants, with the expectation that they will repopulate an area from seeds in the soil.
- Weakening established plants with the hope that they will be more susceptible to mortality in the future or that their seed production will diminish.
- Thinning plants, where some plants in a population are killed but many are not.
- Eliminating seed production by damaging the top growth of plants.

It is tempting to try to eradicate all weed populations because this represents the highest degree of control. However, eradication is not practical for most weed species and infestations because of the high level of effort involved. Eradication is generally appropriate only for small infestations of high-priority weed species.

## PREVENTION

The most important weed management action is to prevent weeds from becoming established in the first place. The old adage that “an ounce of prevention is worth a pound of cure” certainly applies to weed management.

There are two fundamental characteristics of weedy species that help explain why weeds become established where they do:

- Weeds specialize in colonizing highly disturbed ground. Weeds possess a number of physical traits that allow them to arrive at disturbed sites sooner and grow faster than other plants. With these advantages they are able to outcompete native species, at least for a time. To counter this factor, avoid wholesale disturbance or destruction of existing vegetation whenever possible. Such disturbance, resulting in bare soil and lack of competing vegetation, creates ideal opportunities for weed colonization. If disturbance cannot be avoided, re-seed or re-plant disturbed areas immediately after the disturbance has ceased. Use native species or carefully chosen non-invasive introduced species so that “vacant” ground is quickly occupied by desirable plants. Extensive disturbances include house, pipeline, service or utility line, road and gravel pit construction, as well as road maintenance. On many properties road maintenance may be the most significant source of drastic disturbance. Work with local road district or state transportation office personnel to control weeds of rights-of-way that affect your property or management area.
  - Weeds tend to invade plant communities that have been degraded by poor land management. Healthy native plant communities resist invasion. For information about establishing and maintaining native plant communities, see the *Native Plant Revegetation Guide for Colorado* (Colorado Natural Areas Program 1998). One of the best ways to avoid damaging plant communities is to manage livestock grazing so it maintains or increases the vigor of native perennial plants, especially grasses. Recreationists can also damage vegetation by overusing popular camping areas and creating social trails. Dense, vigorous stands of perennial grasses are especially resistant to weed invasion. However, certain highly aggressive noxious weeds such as leafy spurge, diffuse knapweed and Canada thistle can invade well-managed lands that have dense, vigorous vegetation.
- ☒ Consider preventive measures that can be used to reduce the likelihood of future weed infestations. List the ones you will use in the Prevention section of the appropriate weed management plan outline.

# WEED PREVENTION BEST MANAGEMENT PRACTICES

**Post this list!**

## **Be Informed**

- Become aware of the problem, and spread the word that noxious weeds are everyone's concern.
- Learn how to identify high-priority weed species in the field so you can spot them while performing other land management activities. Learn how to distinguish native species from weeds - especially native thistles.
- Report new infestations of known weeds (A and B list) AND of those not previously found in the area (C list) to the county weed supervisor or county extension office.

## **Detect Weeds Early**

- Periodically inspect roads to detect new weed establishment on disturbed rights-of-way.
- Periodically inspect ditch and stream banks for noxious weeds whose seeds could be spread by running water.
- Periodically inspect highly trafficked areas such as developed trailheads, parking areas, campgrounds and other heavily used sites for weed infestations.
- Pay particular attention to areas such as riparian areas and salt licks which are heavily used by livestock and wildlife.
- Be extra vigilant where gravel or fill material is brought in from elsewhere; weed seeds in this material can start new infestations, and bare soil provides an ideal environment for weed establishment.



## **Limit dispersal**

- Don't transport flowering plants that you cannot identify.
- Avoid transporting weed seeds which are stuck on clothing, gear, pets, or livestock. Place the seeds in a plastic bag or similar container and dispose of properly.
- Avoid driving in noxious weed infested areas. Inspect vehicles for weed seeds stuck in tire treads or mud on the vehicle and prevent them from being carried to unaffected areas. Don't clean infested vehicles in weed free areas!

- Inspect maintenance or heavy equipment for weed seeds before it enters the property. Require that such equipment be cleaned first to remove weed seeds before being allowed entry. Clean equipment (especially mowers!) which has been used in weed infested areas before moving it to another area.
- Always use hay, straw, or mulch that has been certified weed free.
- Confine livestock for a day or two in a small weed-free pasture before moving them to another weed-free pasture.
- Make sure that pack animals used in back country areas are fed hay that is certified weed-free. Remove weed seeds from pack animals, before leaving an area, by brushing them thoroughly and cleaning hooves. Post signs to this effect to encourage visiting riders.
- If you find a small number of isolated noxious weeds that have no flowers or seeds, pull the weeds and leave them where you found them to dry out. If flowers or seeds are present, place the weeds in a plastic bag or similar container and dispose of properly.

## **Minimize disturbances**

- Restrict travel to established roads and trails whenever possible.
- Don't drive through sensitive areas.
- Limit the formation of social trails and dispersed campsites.
- Avoid leaving piles of exposed soil in construction areas. Cover with plastic, and revegetate with native species as soon as possible. If possible, spread material excavated during trail construction back on the trail instead of piling it on the side.
- Avoid overgrazing, especially in sensitive areas.
- Move salt licks frequently and keep salt in a shallow container to minimize soil disturbance.

## **Establish and maintain native plant communities**

- Re-seed drastically disturbed areas immediately after the disturbance ends. Perennial native grasses are especially valuable for re-seeding.
- Defer livestock grazing on re-seeded areas for at least one growing season to permit desirable plants to establish.
- Limit use of fertilizers when reseeded; their use may favor weeds over native perennial species.

## PULLING

Pulling refers to using your hands or simple implements to uproot plants.



### **Pulling works best for**

- Small infestations of weeds that can be pulled one patch at a time.
- Annual and biennial plants (although seed banks will remain for some time).
- Shallow-rooted plant species that do not resprout from any residual roots.
- Plants growing on sandy or gravelly soils. If possible, concentrate pulling when the soil is moist and soft; for example, after a heavy, soaking rain.
- Situations where chemicals, motorized equipment or livestock cannot be used or are undesirable.
- Eliminating or reducing seed production in small infestations.



### **Pulling has limitations such as**

- Pulling generally does not remove the entire weed root system except under the most favorable circumstances. Thus, pulling is often ineffective for killing rhizomatous weed species such as Canada thistle, field bindweed, Russian knapweed, leafy spurge, or yellow toadflax even if used in conjunction with other techniques. However, if your goal is reducing seed production, pulling may be very effective. ***If pulled weeds contain seeds, they should be removed from the site and burned or disposed of in a landfill. Don't compost this material!***
- Pulling will not reduce a soil seed bank, although it can keep a seed bank in the soil from increasing.
- It is not cost effective for large infestations, due to the labor involved. Pulling may not be cost-effective for small infestations, either, unless plants are easy to pull and a volunteer work force is available.

These weed species are good candidates for pulling:

Blue mustard  
Common mullein  
Dalmatian toadflax  
Flixweed  
Green foxtail  
Yellow foxtail  
Jointed goatgrass  
Musk thistle  
Oxeye daisy  
Puncture vine  
Russian thistle  
Plumeless thistle  
Scotch thistle  
Bull thistle  
Myrtle spurge

### **Pitfalls of pulling include**

- Volunteer burnout from endless hours of boring work.
- Lack of psychological reward if the results of pulling are not apparent.
- Soil disturbance which stimulates germination of weed seeds in soil, as has been noted with diffuse knapweed.

- Temporarily creating bare soil and providing more sites for weed seed germination and establishment.
- Some weeds produce chemicals that can cause allergic reactions or dermatitis in some people. Always wear work gloves and a long-sleeved shirt for pulling plants. Wash your hands with soap and water afterwards.

### **Resources for pulling include**

- Volunteers for publicly owned natural areas or those owned or managed by land trusts. Land managers can work with local chapters of service clubs and environmental organizations such as the Lions Club, Rotary, Audubon Society, Colorado Native Plant Society and Sierra Club.
- Crews from the local county jail may be available for a variety of land stewardship tasks on public lands and land trust properties including pulling weeds.
- Persons in the criminal justice system who need to donate time to community service projects may also be available for work on public or land trust lands.
- Tools are commercially available for pulling shrubs and small trees from the ground. The Weed Wrench™ is designed for small trees and shrubs, while the Root Talon is designed for shallow-rooted shrubs and small trees and tap-rooted herbaceous species with thick stalks such as teasel and mullein (see Appendix 1, page 87, for further information.).
- Local youth may be available for hire at an affordable price during summer vacation.

### **Cost of pulling**

- Labor is the primary cost associated with pulling. Labor costs vary widely depending on local conditions. A recent study in Montana found that hand pulling alone was effective at reducing flower production of spotted knapweed, but that it was 70 – 500 times more expensive per acre than the other treatments tested (Heap 1999).
- Disposal of flowering or post-flowering plants.

## **MOWING AND CUTTING**

Mowing and cutting employ mechanical or hand tools to sever the aboveground portion of a plant from its roots.



### **Mowing and cutting work best for**

- Large, relatively flat and dry areas that can be mowed with few safety or equipment concerns.
- Preventing tall, erect biennial weed species such as mullein and teasel from setting seed when other control techniques are not feasible.

- Preventing the “tumbling” action of certain weed species such as diffuse knapweed, kochia and Russian thistle that spreads seeds of these species across wide areas.
- Weakening weed plants by depleting root and rhizome reserves through repeated mowing, in cases where such mowing can be conducted efficiently.
- Combining with other control methods, such as herbicide treatment. Cutting can be extremely effective for killing certain trees and shrubs if it is combined with herbicide treatment of the cut stumps. For example, cutting the stems as close to the ground as possible in the fall and immediately (within 30 seconds) painting the cut stumps with triclopyr herbicide kills tamarisk, Russian olive, Siberian elm, and crack willow.
- Large-scale restorations where weeds need to be controlled during the first growing season or two. In these situations, set the mower blade height relatively high so as to cut the taller weeds but to not cut the shorter, slower-growing desirable species.
- Relatively small areas where adequate labor is available.
- Small infestations of fleshy-stemmed biennial thistles are easy to cut with a sharp machete. These thistles include Scotch, musk, plumeless, and bull thistles.



#### **Mowing and cutting have limitations such as**

- Rarely killing weeds.
- Sites that are inaccessible or too rocky cannot be mowed, although weed whips and machetes can be effective in such situations.
- Having to repeat mowing frequently for control to be effective.
- Cut plants resprouting to larger sizes than prior to cutting (tamarisk, Russian olive).
- Weakening some rhizomatous plants only slightly (for example, Russian knapweed) unless the frequency of cutting is very high.

#### **Pitfalls of mowing and cutting include**

- Failing to remove and dispose of cut stems if they contain seeds.
- Dislodging rocks from the mower may be dangerous to the mower operator.
- Turning annual or biennial plants such as diffuse knapweed into short-lived perennials through repeated mowing.
- Weed seeds spread by mowing equipment to areas previously free of infestations. Clean equipment which has been used in weed infested areas before moving it to another area. Make sure that borrowed or rented equipment is free of weed seeds by inspecting equipment before it enters your property. Or you can insist that the equipment must be cleaned first.

#### **Resources for mowing and cutting include**

- Ranchers and farmers that have the needed equipment on hand. They may be willing to contract with you to mow or cut weeds.
- Rental stores which have such equipment can be especially useful for suburban landowners.
- Weed whips can be useful for small, isolated or relatively inaccessible areas.

- Chain saws are recommended for trees and large shrubs such as Siberian elm, tamarisk, and Russian olive.
- Double-action loppers are useful for smaller shrubs and tree saplings.

### **Cost of mowing and cutting**

- Can be relatively low per acre for large areas that can be mowed.
- Can be reduced if you can trade goods or services with a neighbor, especially if the neighbor is motivated by the prospect of reduced weed infestations on his or her property.
- A tractor with a brush hog rotary mower costs about \$80 per hour or about \$50 - \$75 per acre.
- A three-person crew with weed whips costs about \$30 per hour.
- Equipment cost for cutting is modest, with a weed whip, a chain saw and a double-action lopper costing about \$800 total.
- Labor costs can be a barrier to cutting large areas of weeds such as tamarisk or Russian olive.

## **CULTURAL CONTROLS**

Cultural controls seek to control weed problems by establishing desired plant species. Cultural techniques manipulate the plant community through cultivating (cutting through and turning over the soil), re-seeding, fertilizing and irrigating.



### **Cultural controls are most useful for**

- Large restoration projects. Cultivating is often necessary to reduce the number of weed seeds in the soil before planting desirable plant species. Cultivating for a year prior to reseedling kills weeds that have sprouted since the last cultivation and progressively reduces the bank of weed seeds. *Cultivation is not usually appropriate for natural areas because cultivation causes major disruption of established plant communities, and renders them susceptible to weed infestation.*
- Re-establishing native plant communities on disturbed or depleted areas so desirable plants can prevent or reduce weed infestation. *Disturbances such as pipelines, temporary roads, and construction sites need to be re-seeded immediately once the work is completed.* The *Native Plant Revegetation Guide for Colorado* (Colorado Natural Areas Program 1998) discusses this subject in great detail and provides practical advice to landowners and land managers. Copies are available from the Colorado Natural Areas Program.



### **Cultural controls have limitations such as**

- Cultivating is not normally suitable for natural communities.
- Cultivating is appropriate only for restoration of drastically disturbed sites.
- Lack of seeds from locally adapted plants.
- Lack of seeds of certain native species, especially forbs and shrubs.

### **Pitfalls of cultural controls include**

- Seed mixes may be contaminated with weed seeds.
- Cultivation may result in wholesale germination and establishment of weed species if there is not adequate follow-up weed control.
- Temporary cover crops such as wheat, rye or barley used to reduce soil erosion must be mowed or grazed to eliminate their seed production.
- Promoting weed growth by adding unneeded nitrogen fertilizers. Native plant species are generally adapted to low-nitrogen conditions, while weed species are adapted to high-nitrogen conditions. Only add nitrogen fertilizer if tests show that soil nitrogen levels are insufficient to support native species.
- Common components of commercial seed mixes such as yellow sweetclover, smooth brome, and Kentucky bluegrass are often considered weeds in the context of natural lands and natural areas.
- Importing weed seeds on borrowed or rented equipment. You can reduce this risk by inspecting equipment before it enters your property or you can insist that the equipment must be cleaned first.

### **Resources for cultural controls include**

- Local farmers and ranchers who probably have all the necessary equipment for hire.
- Seed companies. See the *Native Plant Revegetation Guide for Colorado* for a list of seed companies.

### **Cost of cultural controls and reseeded**

- A typical cost of contracting out the cultivation of a 10-acre restoration area can range from about \$40 - \$100/acre, and may include a base fee for mobilizing equipment of something on the order of \$1000, assuming the equipment is available for hire locally.
- The cost of reseeded a construction site should be included in the cost of the project.
- The cost of seed is highly variable depending on species and availability. Common native perennial grasses commonly cost between \$3 - \$10 per pound. The cost of seed alone for reseeded an acre of land could vary from \$10 - \$50 per acre.
- A low-cost alternative to seeding is to use native (weed free) hay as a mulch and seed source.

## LIVESTOCK GRAZING

Land managers can use cattle, sheep and goats to selectively overgraze certain weed species, thereby weakening them. In cases where desirable native species are not attractive to livestock, grazing may favor these species over weeds.



### **Livestock are most useful for**

- Weeds that are palatable (at least at some point during the year) and non-toxic to livestock. Weeds vary greatly in their palatability to types of livestock. Generally speaking, the preference for grasses declines from horses to cattle to sheep to goats. Furthermore, goats and sheep are more likely than horses or cattle to relish broadleaf weeds (forbs).
- Leafy spurge control. Goats and sheep are very effective control agents for all but the smallest infestations, especially in riparian areas.
- Low-level, widespread weed infestations where other control techniques are not cost-effective.



### **Livestock have limitations such as**

- Lack of availability of goats and sheep or even cattle when and where you need them.
- Need for water and fencing or herding to control livestock movement.
- The need to manage the intensity and duration of livestock grazing carefully to avoid overgrazing, and allow desirable species to recover from grazing impacts.
- Areas where predators such as coyotes, mountain lions and black bears may kill grazing animals, especially sheep and goats.
- Using the proper kind of animal to manage the weeds on your property.
- Need for someone with knowledge of animal husbandry to manage the animals.
- Palatability of weeds varying widely throughout the growing season. For example, young shoots of Canada thistle are very palatable to cattle, while old, mature stalks are not. However, palatability of many weeds can be greatly increased by spraying them with a dilute solution of molasses.

### **Pitfalls of livestock include**

- Expecting livestock to control weeds without close management. Simply turning animals into a pasture and expecting weed problems to vanish would likely be counterproductive.
- Failing to manage the intensity and duration of livestock grazing to prevent the animals from depleting the desirable plant species they are grazing, or creating disturbance which favors the establishment of weeds.
- Spreading weed seeds in fur or in manure when animals are moved from one area to another. Grazing should be done before weeds set seed.

- Toxicity of weeds such as poison hemlock, halogeton, St. Johnswort and Russian knapweed to grazing animals; toxicity can vary greatly by type of animal.

### **Resources for livestock include**

- Contract grazing operators, typically using sheep and goats, are now entering the market place for the express purpose of controlling weeds (see Appendix 1, page 87).
- Neighbors with livestock are obvious allies in weed control and sources of grazing animals. They may be willing to provide the animals free of charge to you in exchange for a free grazing opportunity.
- There may be a potential profit opportunity where weeds could be turned into dollars in the form of specialized animal products.

### **Cost of livestock include**

- Infrastructure such as fencing and water, including capital and maintenance. Cost of fencing is highly variable depending on soil conditions, access and the type of fencing. Modern electric fencing is available that is much less expensive than barbed-wire fencing. Electric fence can be erected on a temporary basis while the animals are grazing then removed once grazing is finished. There are many sources of electric fence materials.
- The cost of contracting with a person to supply and manage grazing animals. You can expect to pay from \$19 - \$38 per acre to rent goats and sheep for the grazing season.
- Cost of creating a holding area to confine animals (for 10-14 days) which have been grazing weedy areas where weed seeds are present.

## **BIOLOGICAL CONTROL AGENTS (INSECTS)**

Biological control agents are organisms (usually insects) that are deliberately introduced to an area to control weeds. The aim of biological control is not eradication, but rather to exert enough pressure on a weed to reduce its abundance to acceptable levels (Wilson and McCaffrey 1999).



### **Biological control agents are most useful for**

- Reducing seed production or weakening plants.
- Large, dense infestations where other control methods are not cost-effective.
- Situations where a reduced but effectively permanent presence of a noxious weed species is acceptable.

These noxious weed species have biological control programs in Colorado:

- Leafy spurge
- Diffuse and spotted knapweed
- Russian thistle
- Puncturevine
- Musk thistle
- Yellow and Dalmatian toadflax
- Bull thistle
- Canada thistle
- Russian knapweed
- Purple loosestrife



### Biological control has limitations such as

- Failing to eradicate the target plant species. Do not use biocontrol agents where you seek to eradicate a weed population. Eradication of weeds with biological agents never occurs.
- Use of biological control is effectively an admission that a particular weed species is here to stay and that this is acceptable.
- Feasible for only a handful of weed species due to the high cost of finding, screening and testing potential control organisms. Biological controls have a mixed record with some tremendous successes but also with many failures.
- Rarely successful as the sole means of control of a weed species.
- Lack of effective biological control agents for most noxious weed species.
- Biological control agents being unavailable when you want them.
- Necessity of having a reservoir of host weeds to support biological agents over the long term. Thus, it may be necessary to leave some weeds to support populations of control organisms. This may be unpopular with neighbors or the public.
- Degree of control is variable and will take several years to achieve.

#### The biology behind biological control

In its native environment, a plant is constantly attacked by a variety of organisms. Herbivory by insects and other invertebrate animals, and infection by fungi, bacteria and viruses reduces the ability of plants to grow and reproduce, which regulates the population size of a species. When plants are transported to a completely new environment, insects and other organisms in the new environment may not be adapted to feed on or otherwise control the plant species. If this is the case, the introduced plant species may be able to expand its population size enough to become a troublesome weed.

One method of controlling weeds involves finding organisms in the plant's native environment that attack the plant and reduce its growth and / or reproduction. After a lengthy period of laboratory and field testing to determine if the organism is likely to attack non-target plants, these organisms may be released to control the weed in its new environment. The federal government approves individual insect species for release as biological control agents. Generally, federal land management agencies are not required to perform additional reviews to release approved biocontrol agents. Other organizations may have internal policies that govern the intentional release of biological control agents.

#### Pitfalls of biological control agents include

- Insects attacking beneficial, non-target plants. For example, the seed weevil *Rhinocyllus conicus* that has been used to control musk thistle also attacks native thistles. There are indications that this weevil is adversely affecting a rare thistle (*Cirsium ownbeyi*) in Colorado (C. Dawson, pers. comm.). The weevil *Larinus planus*, introduced for control

of Canada thistle, has been reported to attack native thistle species as well (S. Louda, pers. comm.). Insects that have been released to control St. Johnswort also feed on native *Hypericum* species, and some insects released for leafy spurge control also attack native spurge species (Wilson and McCaffrey 1999).

- Inability to establish populations of biological control organisms for reasons relating to climate, soils and so forth that are not well understood.

### **Resources for biological control agents include**

- The Colorado Department of Agriculture's Insectary in Palisade rears biological control insects and provides them free of charge to Colorado residents. Consult your county weed supervisor to find out if biological control agents have been used successfully in your area or call the Insectary at (970) 464-7916.

### **Cost of biological control agents**

- Biological control agents are available free of charge from the Insectary. Availability is limited.
- Insects are available for sale from commercial sources, often for several hundred dollars for a sufficient number of insects for one release.

The Biological Pest Control Section of the Division of Plant Industry has ongoing biological control programs for thirteen noxious or problem weed species. The primary function of the Section is the rearing and releasing of natural enemies for control of specific plant and insect pests. The rearing is done at the Insectary at Palisade. Currently, a total of 29 species of weed predators are being cultured, released, and established on weed infestations throughout the State. Most of these species are available if they have been established in Colorado. The Biological Pest Control Section encourages anybody who is interested in these programs to call for the insects. The requests are put on a list and when the insects are available, the land manager is contacted to arrange the release. See Appendix 8 (page 311) for a list of the insects available for control, the weed species they control, and the address of the Insectary.

## **HERBICIDES**

Herbicides are chemicals that kill or injure plants.

There are many kinds of herbicides; some are derived from plants and others are manufactured synthetically. Herbicides can be classified in terms of their mode of action. These chemicals include growth regulators, amino acid inhibitors, grass meristem destroyers, cell membrane destroyers, root and shoot inhibitors and amino acid derivatives which interfere with plant metabolism in a variety of ways. See Appendix 9 on page 315 for a brief description of the

modes of action of different herbicides. This appendix also contains a list of commonly used herbicides, along with active ingredients and trade names.

The choice of which herbicide is best for a particular situation depends on the target weed species, the presence of desirable plant species, soil texture, depth and distance to water, and environmental conditions (Bussan and Dyer 1999). For some suggestions on how to choose an herbicide, see the article entitled “Herbicide Selection” which is reprinted in the next chapter (page 69).



### **Herbicides work best for**

- Eradicating some weed species in certain situations. Herbicides are most effective on pure stands of a single weed species where desirable non-target plants are scarce or absent. In this situation, one often has the option of selecting from several different herbicides.
- Rhizomatous weed species that are unpalatable to livestock, require repeated pulling or cutting for control, or are located in remote areas where pulling or cutting are not feasible.
- Small patches of weeds where hand pulling or cutting is not effective or feasible.
- Use in combination with other control methods. For example, Canada thistle can be controlled by repeated cutting during the growing season followed by treatment with clopyralid herbicide in the fall. As noted previously, tamarisk, Russian olive and Siberian elm can be controlled very effectively by cutting stems very close to the ground in the fall then immediately spraying or painting the cut stems with triclopyr herbicide.



### **Herbicides have limitations such as**

- Damaging or killing non-target plants. Herbicides are not completely selective in their toxicity to the target plant species. Effects on non-target plants can be minimized by selecting an appropriate herbicide and using a wick or a backpack sprayer. A wick is made from adsorbent material and saturated with herbicide. This wick is rubbed directly against the weeds so the herbicide is not applied to adjacent, desirable plants.
- Difficulty of using herbicides to control small weeds when they occur among taller desirable plant species.
- Toxicity to humans to varying degrees. Thus, their use is regulated by federal and state laws. People who use herbicides need to know these regulations. Certain herbicides are classified as “restricted use herbicides” whose application is limited by federal and state regulations.
- Restricted use herbicides are often available only at licensed outlets such as your local farm coop or by ordering through reputable distributors.
- Property owners must possess a private applicator’s license to apply a restricted use herbicide on their property. This license is obtained by passing a test administered by the U. S. Environmental Protection Agency in Denver. Call the Private Pesticide Applicator office at (303) 312-7283 for more information.

- Herbicides must be applied in conformance with the label. With herbicides, the label is the law, and applying an herbicide beyond the bounds specified on the label is illegal.
- Certain herbicides may not be used around or on water. This is an important consideration for weeds such as Canada thistle, perennial pepperweed, purple loosestrife, and tamarisk that grow in wetlands or riparian areas.
- One must possess the proper equipment and requisite knowledge to apply chemicals safely. Proper clothing must be used, and materials to contain spills must be on hand when using herbicides. See Appendix 10 on page 321 for Herbicide Use Guidelines and tips on how to use herbicides properly and safely.
- Herbicides can move beyond the area where they are applied and affect non-target plants and animals. This drift can be eliminated by using a wick or reduced by spraying under calm wind conditions and by adjusting the sprayer apparatus to produce large droplets.
- Populations of weeds may develop resistance to a particular herbicide over time.
- Opposition to the use of chemicals in the environment, especially in urban areas. Local opposition in some areas may pose challenges for the use of some or all herbicides.
- Like most other control methods, herbicides are short-term solutions that do not address reasons for weed problems in the first place. Therefore, spraying an herbicide treats a symptom of a problem. Even if an herbicide eradicates a weed infestation, another infestation may appear if the underlying cause of the infestation persists.

#### Pitfalls of herbicides include

- Simplifying diverse plant communities by suppressing certain plant species, although this effect may be temporary.
- Herbicide applicators who cannot distinguish noxious weeds from desirable plant species, resulting in accidental damage to the latter.

#### Resources for herbicides include

#### Some herbicide terminology

Formulation refers to how the herbicide is packaged. Sprayable formulations are diluted with water or oil-based carriers and sprayed on vegetation or soil. Dry formulations are granules or pellets and are spread directly on the soil. An herbicide **formulation** consists of an active ingredient, an inert carrier, and possibly adjuvants. The **active ingredient (a.i.)** is the chemical which is primarily responsible for the herbicide's toxicity to plants. The **inert ingredient(s)** or **carrier** is a solvent or dilutant that makes the active ingredient soluble and able to penetrate plant tissues. Water is the most commonly used carrier. Hard or dirty water can decrease herbicide effectiveness, especially for glyphosate and 2,4-D salt or amine formulations (Bussan and Dyer 1999).

**Adjuvants** are substances added to a formulation to increase the effectiveness of the active ingredient. These include surfactants, antifoaming agents, activators, drift control chemicals and dyes. The actual volume of spray solution is called the **spray gallonage**. Using the correct spray gallonage is important for ensuring good coverage of weed foliage with foliar-active herbicides (Bussan and Dyer 1999).

Note that herbicide manufacturers are not required to disclose all ingredients in their products. Inert ingredients and adjuvants may also be dangerous chemicals -- always check the Material Safety Data Sheet (MSDS) for an herbicide. Remember, **THE LABEL IS THE LAW**. It is illegal to apply herbicides beyond the amounts specified on the label. If you have questions about a particular herbicide, call the 1-800 number on the label, or contact your county weed supervisor.

- The Division of Plant Industry in the Colorado Department of Agriculture can direct you to information about herbicides.
- The Internet is a great way to access lots of information, such as the National Pesticide Telecommunications Network at <http://ace.orst.edu/info/nptn/>. See Appendix 1 (page 87) for other Internet resources.
- Herbicide labels are an important source of information that people who use herbicides need to read carefully.
- Professional, licensed herbicide applicators are knowledgeable about herbicides. Most readers of this handbook will probably want to use the services of an applicator familiar with natural area situations, rather than just lawns and turf. Your county weed supervisor can provide you with the names of licensed applicators in your area. A directory of commercial applicators is also available from the Colorado Weed Management Association web site: [http://www.cwma.org/3\\_weed\\_control.html](http://www.cwma.org/3_weed_control.html).
- Chemical company sales persons are also sources of information, particularly about the products they sell.

### Cost of herbicides

- The cost of herbicide alone commonly runs from about \$5 – \$20 per acre.
- The cost of herbicide application (not counting the chemical) depends greatly on the size of the area being treated, the chemical(s) are being used, and whether you apply the herbicide yourself or hire someone to do it for you. Cost for custom application runs from about \$50 - \$75 per acre for areas from one to one hundred acres using small equipment. For larger areas that are accessible for large equipment, costs can drop dramatically. Aerial application can run about \$20 per acre (not including the cost of the herbicide) for areas over one hundred acres. Note that any person who applies herbicide for a fee must be licensed by the State of Colorado.

### Herbicide resistance

Starting with the introduction of 2,4-D in 1946, agrochemical companies have manufactured and brought to market a wide variety of herbicides. The success of herbicides and other crop protection chemicals have revolutionized weed management, farm practices and food production. However, the utility of herbicides is being threatened by the appearance of herbicide resistant weeds. In any weed population, there are likely to be individual plants which are able to survive herbicide treatments which kill most of the population. This naturally occurring heritable characteristic enables these individuals to survive and reproduce, producing a population which becomes resistant to herbicides over time. Currently, there are over 216 herbicide resistant weed biotypes worldwide with an average of nine new cases per year (Heap 1999). In Colorado, three weed species have been listed as herbicide resistant (Heap 1999). Redroot pigweed (*Amaranthus retroflexus*) has become resistant to atrazine, wild oat (*Avena fatua*) has become resistant to dicoflop-methyl, and kochia (*Kochia scoparia*) has become resistant to both atrazine and metsulfuron-methyl (Heap 1999).

## PREScribed BURNING

Prescribed burning is planning, setting and managing fires to accomplish resource management objectives.

Prescribed burning is a complicated subject and will not be discussed in great detail here. Interested readers are referred to the many references on the subject, two of which are listed in Appendix 1 on page 87. Consult land managers and scientists who have experience with local conditions if you are contemplating prescribed burning.



### **Prescribed burning works best when**

- The noxious weed species you want to control is much more susceptible to the effects of burning than are the intermingled desirable plant species.
- Controlling cool-season grasses in prairie restorations.
- A proper monitoring plan is in place to evaluate the effects and success of the project.



### **Limitations of prescribed burning include**

- The need for intensive planning to insure that the burn will be safe and accomplish the intended resource management objectives.
- Smoke management problems, especially in urban areas, that limit your ability to burn.
- Availability of crew members who have “red cards” that signify a minimal level of fire training.
- Availability of experienced crews to manage the prescribed burn in your particular fuel type(s).

### **Pitfalls of prescribed burning include**

- The possibility of burns getting out of control and damaging property and endangering human life.
- Liability issues if a fire gets out of control.
- Arid environments can not tolerate frequent burning.
- Massive germination and establishment of weed seeds following burning. However, this may be advantageous, in that it may assist in the depletion of the bank of weed seeds in the soil, if you are prepared to control the resulting weeds.

### **Resources for prescribed burning include**

- Colorado State Forest Service. Trained CSFS staff can prepare prescribed burn plans for private landowners for a modest charge.
- In-house fire experts of state and federal land management agencies can advise public land managers about prescribed burning and prepare prescribed burn plans.

- Certain county open space programs have in-house fire experts who may be willing to share their experience with you and to direct you to additional knowledgeable people.
- Private consultants and contractors who specialize in prescribed burning.

☒ Read the species profile for each species to be controlled. Become familiar with the characteristics of the plant, and the available control measures for each species.

#### **Why an integrated approach is important**

Jim Smith, *Park Manager, Chatfield State Park*

Jim has been doing weed management since the late 1980s. His first efforts were with Canada and musk thistle. Prescribed burning (then a fairly new technique in the metro region) was tried, but with little success. "It was eye-opening to me at the time to see that one method wasn't likely to work, and that it would take combined methods over several years to have a positive effect." Weed management techniques in use at Chatfield now include mechanical control and handpulling, biocontrol and herbicides. Jim offers the following advice:

- With herbicides, more is not necessarily better. Timing and application rates are the keys to good results. Rely on the information available from herbicide labels and research - it gives the best recommendations.
- It is important to find the appropriate chemical, *and* to use it in combination with other control methods.
- Reclamation and reseeding must be part of a weed control plan from the start. It is critical to prevent new weeds from taking over areas where other weeds have been killed.
- Public education is essential - try to get information about the weed problem out to the public, and use a variety of activities to communicate ideas. The increasing urbanization of the Chatfield area has made controlling weeds more of a challenge. Managers must achieve a balance of being more cautious and sensitive to neighbors and the environment while still being effective on weeds.
- It is also helpful for managers to lower their initial expectations of success, and tackle smaller patches and problems first. Success with these efforts will encourage you to work on bigger things.

"My approach has been to work with lots of people doing research, and to network with similar field people in other agencies. I've found that there are a lot of answers out there from others who have had successes. It's better to go get information from others rather than trying to re-invent the wheel yourself."

## VII.

# INTEGRATED WEED MANAGEMENT

No single management technique is perfect for all weed control situations. Multiple management actions are required for effective control. The strategy of using an integrated selection of management techniques has been developed for use in a variety of “pest” control situations, including plant pests, or weeds. As used in this guide, Integrated Weed Management (IWM) is a process by which one selects and applies a combination of management techniques (biological, chemical, mechanical, and cultural) that, together, will control a particular weed species or infestation efficiently and effectively, with minimal adverse impacts to non-target organisms. Ideally, these management techniques should be selected and applied within the context of a complete natural resource management plan.

Most traditional weed management treats only the symptoms of weed infestation, typically by using herbicides to kill weeds. IWM differs from ordinary weed management in attempting to address the ultimate causes of weed infestation, rather than simply focusing on controlling weeds. Although focusing on the fundamental causes of weed invasion and persistence is more demanding than simply spraying weeds, the rewards are far greater and are worth the effort. Over the long run, IWM should lead to greater success in meeting management objectives.

IWM is “predicated on ecological principles and integrates multidisciplinary methodologies in developing ecosystem management strategies that are practical, economical and protective of public and environmental health” (Piper 1991). IWM seeks to combine two or more control actions which will interact to provide better control than any one of the actions might provide. However, even if multiple control actions do not interact, their additive effects can mean the difference between success and failure. In addition, employing multiple control actions should increase the likelihood that at least one of them will control the target weed species. *IWM is species-specific, tailored to exploit the weaknesses of a particular weed species, site specific, and designed to be practical with minimal risk to the organisms and their habitats.*

## GENERAL PRINCIPLES

IWM requires landowners and managers to understand the biology and ecology of the weed species and its environment before selecting control actions. With scientifically valid information, landowners and managers can select the most effective, efficient, environmentally sound and socially acceptable methods to control weeds (Brown et al. 1999). Read the relevant weed profiles in Appendix 4 beginning on page 117 carefully before you develop IWM approaches for your problem weed species.

If you have completed the steps in chapters 2-6, you will have compiled a variety of information about your property and its weed control requirements. Now that you have identified which

species and which infestations are high priority for control, use the following general principles and strategies in your selection of control measures and formulation of an IWM plan.

## **1. WORK TO ESTABLISH AND MAINTAIN FUNCTIONING NATIVE COMMUNITIES**

### **Grazing Management**

Grazing is the most extensive land use in Colorado, and poorly managed livestock grazing can contribute greatly to the invasion and spread of noxious weeds. Therefore, proper management of livestock is an essential component of integrated weed management for managing weeds on lands that are grazed. Perhaps the most important elements of a grazing plan are moving livestock from pasture to pasture to avoid overgrazing and to provide plants with adequate time to recover following grazing.

### **Other Land Use Practices**

Land use practices other than grazing can also help or hinder the spread of weeds. Look for instances where irrigation, haying, or recreational use may be contributing to the degradation of native plant communities, or otherwise promoting the invasion and spread of noxious weeds, and take steps to alter these practices as necessary. In some situations, a conservation easement may motivate these changes in land management practices.

### **Restoration and Revegetation**

One way to combat the problem of invasive noxious weeds is to use native plants for landscaping, revegetation, and reclamation. IWM considers the broader natural systems in which a weed species or infestation occurs and attempts to manipulate these systems in ways that result in control of the weeds in question. Control often is geared toward improving the health of desirable plant communities so they can withstand future weed invasion. Use native species for reseeding, and plant native trees or shrubs as appropriate. Encourage the growth and persistence of native species by taking care not to damage them or alter their habitat with unsuitable land management practices. For detailed information see the *Native Plant Revegetation Guide for Colorado* (CNAP 1998).

## **2. IMPLEMENT APPROPRIATE PREVENTION METHODS**

IWM also includes combining preventive measures with normal land management activities and weed control actions. Preventing weeds from invading a site is the most effective and least costly method for controlling weeds. As you consider control actions, remember that you will need to ensure that application of these actions does not contribute to the spread of noxious weeds.

## **3. CHOOSE APPROPRIATE CONTROL ACTIONS**

Selecting appropriate control actions requires a detailed knowledge of the biology and ecology of the target weed species. The selected control actions should ideally be ones that are:

---

**Applied at the most effective time**

Most control actions are effective only during certain periods of the target species' life cycle. Treatments should be applied at the point in the life-cycle of the weed when it is most vulnerable, *and* at a time when the least damage will be done to its natural predators and other non-target species.

**Least damaging to non-target organisms, including natural weed control organisms**

Landowners and managers should carefully consider the likely effects of available control techniques on both target and non-target species before deciding which combination of control measures to use. Non-target organisms may include sensitive species, native plant communities, wildlife, areas revegetated to control weeds, insect pollinators, insects that feed on target weed species, and plant species that compete with the weeds you are trying to control. The selected control actions must not significantly damage these non-target organisms or lead to the creation of further problems.

**Least hazardous to human health**

Herbicides can be injurious to human health if not used correctly. In fact, one of the driving forces behind IWM is the reduction of unnecessary pesticide use. Chemicals should be carefully chosen to minimize their potential toxicity to humans. Successful weed management involves more than just spraying weeds. Similarly, mechanical tools such as mowers and chainsaws can be dangerous if not handled properly. Make sure you are familiar with the proper operation of such tools.

**Least damaging to the general environment**

Using herbicides judiciously is important to avoid environmental contamination, especially around water. Certain formulations of herbicides cannot be used in aquatic situations or where ground water is close to the ground surface. In addition, timing of herbicide application is important to maximize the effectiveness of the chemical on the target weed, as well as to reduce the possibility of adverse side effects.

**Most likely to reduce the need for weed control actions over the long-term**

Control techniques fall into two general categories: those that seek to prevent weeds from establishing, and those that deal with weeds which are already present. Preventive and cultural measures to reduce soil disturbances or to reduce the input of weed seeds to an area, re-seeding existing disturbed lands, and altering grazing practices to promote more vigorous stands of perennial plants are actions which work to prevent weed establishment. Actions which address existing weeds include pulling, mowing, applying herbicide, prescribed burning, grazing or releasing biological control insects. Any combination of these management actions which addresses the underlying causes of weed infestation and spread is likely to be the most beneficial for controlling weeds over the long run.

**Most easily implemented**

Control techniques which are easier to apply are more likely to be completed, and therefore most likely to have an effect on weeds.

### Most cost-effective in the short and long term

Consider the benefits and the costs of the possible control actions. For example, is the potential damage to desirable vegetation from an herbicide worth the risk? Is the potential for contaminating a stream with an herbicide outweighed by the benefits of controlling a noxious weed? Is the potential for spreading weed seeds by driving your vehicle into an area infested by weeds outweighed by the increased ease of controlling weeds?

## GENERAL STRATEGIES

Remember that weed management actions need to support your land management goals and your weed management objectives. Generally speaking, weed control objectives will be to eradicate, suppress or contain weed populations.

- **Eradicate** means completely eliminating all weed plants, including live roots, rhizomes and seeds. Eradicating a weed species on a management area is very difficult unless it is present in small numbers.
- **Suppress** means to reduce the abundance of a weed species, typically as measured or estimated in terms of canopy cover or plant density.
- **Contain** means confining an infestation so it does not expand, but does not usually mean reducing the current infestation.

Tailor your management actions to the level of control you are seeking. For example, biocontrol agents might be appropriate for suppressing a weed population but not for eradicating a population.

IWM programs for large weed infestations generally select actions from the following list:

- Preventing weeds from becoming established in the first place
- Altering livestock grazing practices to promote more vigorous plant growth
- Using appropriate types of livestock to graze and thereby weaken weed plants and/or reduce seed production without damaging desirable plants
- Re-seeding with a mixture of competitive, desirable plants, especially grasses, that span the spectrum of growth periods (cool- and warm-season plants) and rooting depths (shallow and deep rooted)
- Releasing biological control insects to weaken weed plants and reduce seed production
- Spraying with an herbicide selected to provide maximum weed control without damaging existing or newly seeded desirable plant species

A successful IWM program must be tailor-made for each situation. There is no cook-book solution that will work everywhere. However, certain combinations of control actions have been successful and are worthy of your consideration:

- Mowing or cutting plus herbicide (see case studies of Canada thistle, perennial pepperweed, and spotted knapweed below)
- Spraying with herbicide followed by reseeding with competitive plant species followed by hand-pulling of residual weed plants (see diffuse knapweed case study)

- Altering grazing regimes plus introducing biological control insects (see musk thistle case study)
- Cutting woody plants followed by herbicide application (see tamarisk case study)
- Grazing with goats plus reseeding with competitive plant species plus introducing biological control insects (see leafy spurge case study)
- Introducing biological control insects with periodic herbicide application (see leafy spurge and purple loosestrife case studies)
- Spraying with herbicide followed with re-seeding with competitive perennial grasses (see Russian knapweed case study)
- Re-seeding with competitive grasses followed by altered livestock grazing regime (see yellow starthistle case study)

Remember that herbicides **must** be applied in conformance with the label. With herbicides, the label is the law. **Applying an herbicide beyond the bounds specified on the label is illegal.** Do not increase the concentration of an herbicide beyond the limits set by the manufacturer. More is NOT necessarily better, and higher herbicide concentrations can damage animals and non-target plants. The presumed safety of a chemical is based on the manufacturer's recommended concentrations only.

IWM prescriptions potentially include the full range of control actions discussed in this handbook, including pulling, mowing and cutting, livestock, cultural controls, herbicides, prescribed burning, and biological control agents. The IWM approach contrasts with the traditional approach of using a single control action, such as applying herbicides, to treat all weed problems. Herbicides are one useful technique but they are not the only method to control weeds, and may not always be the most effective.

## IWM EXAMPLES

The following pages present examples of successful Integrated Weed Management approaches for individual species, as well as examples and advice from people who are working in the field of weed management. Remember that your situation may be different from these examples. Please consider them carefully but don't necessarily copy these examples without modifying them to fit your situation.

**Canada thistle** is a perennial, rhizomatous weed that often grows in moist areas along streams. It has been controlled successfully in many situations with a combination of mowing several times during the growing season followed by application of glyphosate herbicide at the end of the growing season. The mowing weakens the thistle plants and depletes carbohydrate reserves in its rhizomes, allowing the herbicide to have a greater effect on the thistle than it would otherwise. In rough terrain the mowing can be accomplished with a weed whip. In some cases repeated grazing may mimic the effects of mowing. The herbicide can be applied with backpack sprayers or wicks to minimize or eliminate damage to non-target plants. However, remember that certain herbicides may not be used in or around water, where Canada thistle is often found.

**Persistence pays off in Canada thistle management**

Ron Broda, *Vegetation Management Specialist for Weld County.*

Ron began trying to eliminate Canada thistle from approximately 20 acres of a county owned field in late 1995. At that time, the field was essentially solid Canada thistle. In Ron's opinion, when a deep rooted creeping perennial like Canada thistle becomes well established as this stand, root development is so immense and the infestation is so difficult to control, that herbicides must play an important role in an integrated management plan. Thus, the county began a program of mowing and spraying that lasted three years.

The approach taken to deal with this large Canada thistle patch has been to spray with either Telar® (the initial rate used was 1 oz/acre but was increased to 1 1/2 oz/acre due to recommendations from the manufacturer) or Tordon® 22K (1 quart/acre) once in the spring, followed by a mid-summer mowing and a fall herbicide application. Using this approach, the patch has been constantly stressed during the growing season, and the ground has been cleared, making the fall herbicide application even more effective.

After 3 years of this treatment, the stand density has been reduced by 95%. Ron attributes the success of the program to his patience and persistence in using a long-term approach to control deep-rooted creeping perennials (like Canada thistle, leafy spurge, and yellow and Dalmatian toadflax). It is not reasonable to expect to spray a mature stand of one of these species only once and have it eradicated.

On the down side, kochia is now coming up in place of the Canada thistle. So, although the weed management program has been very effective at eliminating Canada thistle, the lack of a revegetation plan has resulted in the replacement of one weed for another. A revegetation/restoration program is now important in returning the land back to a productive state.

Ron says that when dealing with landowners who seek advice when dealing with dense stands of deep rooted creeping perennials, he offers these two bits of wisdom:

- Know you will have to remain vigilant in your efforts
- If you want your ground to return to a useable condition, you must implement a restoration plan

**Diffuse knapweed** is a biennial or short-lived perennial that reproduces solely from seeds.

According to Roché and Roché (1999), the best case scenario for diffuse knapweed control is establishing competitive grass species (through seeding and good range management) that can, with the help of biological control agents, maintain knapweed at low levels. One might initiate control efforts with picloram, followed by re-seeding, improved range management, and introduction of biological control agents, followed by hand-pulling of new plants that arise from residual seeds in the soil. Preventing knapweed plants from blowing into your property area (by using fences or other wind breaks) from adjacent properties is also critical to long-term control.

**Leafy spurge** is a long-lived, rhizomatous perennial that grows in many habitats and sprouts prolifically from its deep roots. Lym (1998) suggests employing four potential control actions: 1) re-seeding with competitive perennial grasses; 2) grazing with sheep or goats; 3) introducing biological control insects; and 4) treatment with picloram herbicide. Of these, sheep or goat grazing and biological controls are more suitable for large rather than small infestations. The combination of herbicide treatment and introduction of flea beetles (biological control insects) works better than either does alone. Likewise, grazing combined with fall-applied picloram +

2,4-D reduces leafy spurge density more than either treatment used alone (Lym 1998). Herbicide should be applied before seed set.

### **Managing Leafy Spurge on a Private Ranch**

Michael Craig, *Pitkin County Land Management and Operations Supervisor*

I have lived most of my life on a ranch that my family bought in 1964 in the Woody Creek area in the Roaring Fork drainage north of Aspen. The ranch land is primarily unimproved sage/gambel oak/service berry/mountain mahogany dominated plant communities. The remainder of the land was cleared in the late 1800s and planted into hayfields and pastures with irrigation ditches to provide supplemental water. For most of the 60s and 70s my family raised cows and grew hay to feed them.

Our weed management efforts were fairly minimal throughout these years because there were not as many weeds in the valley then, and because we were ignorant of new weed species. Thistles of all varieties have always been easy to recognize, and poison hemlock was also well known. Unfortunately, very small infestations of leafy spurge were also present on our property for years before we became aware of its aggressive nature.

In the mid 1980s the new Pitkin County weed supervisor introduced me to many of the noxious weed species, including leafy spurge. At the time, I was managing the irrigation and haying operations for my family. I started informal weed mapping for leafy spurge on as much of our land as possible and soon discovered that we had an extensive infestation. By 1990 Steve Anthony had become the weed supervisor for Pitkin County, and he knew a lot about the most recent management strategies for leafy spurge. He assisted me in formulating a preliminary weed management plan for our ranch. Our control efforts to date have included biocontrol by grazing animals and insect herbivores, herbicide spraying, and preventive land management practices.

We began our management efforts for leafy spurge in 1990 by purchasing 12 Spanish goats as well as a Great Pyrenees dog to guard them. This allowed us to isolate the goats on remote areas of our property without suffering coyote predation problems. We used the goats on plots of roughly one acre for 2 week intervals from late May to early June followed by another 2 week grazing in early fall to deprive the plant of any regrowth and subsequently any storage of energy for the coming winter. This was done for 4 years without any herbicides being used in conjunction with the goats. The results were less successful than we had hoped in light of the high labor inputs for goats. The spurge appeared to be unfazed by the grazing and continued to come back at similar densities every year. However, spraying the grazed areas with Tordon®/2,4-D in the fall of 1994 reduced the spurge cover by an estimated 90%. I would like to do more trials with goats and herbicide because that appeared to be the necessary combination.

The Insectary has also been very helpful in supplying us with flea beetles, which for the past 9 years we have released to areas that have never been sprayed. From my understanding of the dynamics of these beetles, we should start to see results from this control method soon. If the beetles work, it will be worth the wait based on results I have seen in the Meeker area. We have also used our cows to trample the spurge during the spring on this site, which evidently helps the beetles. I'm not sure of the mechanism, but it appears to stunt the plants and allows the beetles a larger window of opportunity to attack the spurge.

The focus of our integrated management plan was to eliminate the vectors that were spreading leafy spurge. Our irrigation ditches were the primary conduits for the spread of this species, and presented special management concerns about herbicides which could be used near water. Our first choice of herbicide was Rodeo, but it proved to be ineffective on leafy spurge. Next we decided to completely shut down some of the ditches that were most infested. This allowed us to use Tordon®/2,4-D which has been the most effective herbicide combination in our area. We have actually shut down one of our ditches for the past 8 years in the attempt to eliminate spurge from within the ditchbanks where it can drop seed into the water. Due to the 'use it or lose it' requirement under Colorado water law, this strategy

may turn out to be too costly to be feasible over the long haul.

Culverting ditches in areas where spraying is not an option (due to adjacent riparian or wetland habitat) is very expensive but highly effective in essentially excluding the spurge from entering the ditch and moving downstream. We installed over 2500 feet of pipe on one ditch so that we could continue to irrigate 20 acres of land downstream of a very dense infestation of spurge. Another management technique that we used was to clean our ditches by hand as often as possible instead of using a dozer to scrape the ditch every year. This reduced the bare and disturbed soil immensely and helped to slow the spread of spurge as well as a host of other weeds, especially thistle.

My overall feeling now is that our strategy is one of containment and not of eradication. I am getting a handle on where the spurge is and am now focusing on eliminating small remote populations and trying to contain the edges of our large infestations. It's going to be a long war, but I hope I can win a few battles.

**Musk thistle** is a biennial plant that grows in dry rangelands. It has been controlled with a combination of altered grazing and introduction of musk thistle seed weevils. Altered grazing regimes reduce the abundance of bare soil and increase the vigor of desirable native plants while the weevils attack the seed heads of the thistle plants, thereby greatly reducing seed production. Once the density of musk thistle is reduced to low levels, it can be controlled through cutting and removing the seed heads before the seeds ripen until the musk thistle seed reserves in the soil are depleted. Spraying rosettes in the fall is effective, but herbicide is much less effective after plants have bolted in the spring.

### **Thrashing Thistles at North Star Nature Preserve**

Steve Anthony, *Garfield County Vegetation Management Director*

North Star Nature Preserve is a 175 acre open space parcel southeast of Aspen, located along the Roaring Fork River in a relatively flat valley surrounded by Smuggler Mountain and Richmond Hill. At one time the area was covered by dense willow thickets, and occasional islands of cottonwoods and spruce. In the early 1950s the landowner cleared the site by hand, machinery and burning, and planted hay over a number of years. With the help of The Nature Conservancy, ownership of the land was transferred to Pitkin County in 1978, and the site is now managed by the Aspen Center for Environmental Studies (ACES).

In order to preserve the land in its natural condition as a public amenity and for wildlife habitat, the area is fenced and public access is only permitted on the north side of the property between Highway 82 and the Roaring Fork River. Guided tours occur on the south side of the River. Except for occasional recreational uses, such as paragliding, fishing, birdwatching, and cross country skiing, the Preserve is left undisturbed.

In the late sixties and early seventies, a new visitor came to Pitkin County and to the North Star Nature Preserve as well. This visitor had wanton disregard for native plants, encroached on open lands, and robbed the native plants of valuable soil nutrients, water, and sunlight. The visitor was of course, the pesky, introduced alien plant *Carduus acanthoides*, commonly known as plumeless thistle. Before plumeless thistle found its way to the high country of Colorado, it was primarily found in the flatlands of Kansas and Nebraska.

For about 15 years both Pitkin County and ACES fought plumeless thistle with a variety of methods including test plots sprayed with Roundup®, grazing by burros, and the introduction of thistle feeding insects. These methods had varying degrees of success, but it became evident that an organized annual

program was needed. ACES and Pitkin County began working together on a cooperative weed management project at the Preserve in 1995. Due to concerns expressed by Heather Hopton, ACES Board Member and also then-chair of North Star's Management Committee, about herbicide use it was decided that ACES and Pitkin County would organize a volunteer hand pulling effort.

The first such effort took place on a Saturday morning in June of that year. Heather made arrangements with a local Aspen bank to sponsor food and refreshments for the volunteers. The Bureau of Land Management designed and distributed tee-shirts with a design of a hand pulling a thistle and the words "*Get a Grip on Weeds*". The County provided a pickup for weed hauling and various hand tools, such as shovels, pruners, and loppers. The event was publicized in ACES' newsletter and in the local papers. Heather also personally called dozens of neighbors and members of ACES.

The first thistle pulling event was a success with over thirty local residents turning out. Although the event was labeled a "thistle-pulling party", other noxious weeds were targeted also. The volunteers gathered at 9:00am Saturday and were given a quick course in weed identification and control techniques by Pitkin County staff. They emphasized that "a thistle is not just a thistle", meaning that one needed to learn if the targeted thorny object of scorn was the biennial, plumeless thistle, or the tougher to control perennial, *Breea arvense* (*Cirsium arvense*), known world-wide as Canada thistle. Those of us in the weed management profession who can spot a knapweed or leafy spurge plant while driving sixty miles an hour on the interstate, sometimes take for granted the subtleties involved in weed identification. *It is difficult for the average layperson to distinguish between species of noxious weeds, especially thistles.* With that in mind, it is best to try to emphasize to folks that there are one or two differentiating characteristics that they should look for. In the case of the two thistles, staff asked the volunteers to look at the stems of the plant. The stem of Canada thistle is relatively smooth, while the stem of plumeless has spiny wings.

Once the volunteers learned how to distinguish between the thistle species, they were able to utilize the proper control technique. The participants learned that since Canada thistle is a deep rooted perennial, it didn't make sense to try to dig up the entire plant. Instead they learned to cut the plant at the base. In the case of plumeless thistle, they were taught to pull the plant (using the right kind of gloves) or try to dig it up. Thus the rallying cry became "C-C and P-P!" -- which translates to "Cut Canada and Pull Plumeless."

Over the next four years the thistle pulling parties turned into "Thrash-a-thistle" Day. These events have continued to be successful for several reasons. One key to success is followup. Most years consisted of two, and sometimes three, Thistle Days. In this way, the weeds that somehow escaped the volunteer's wrath in June were nabbed at a later event in July or August. Another key to success is that the volunteers primarily focused on one 10 acre site of North Star on the north side of the Roaring Fork River. The volunteers have now started working on the more severely infested, remote south side, but only after many years and many "Thistle Days" were spent on the north side.

This project works because of the commitment of the local residents. Amid all the "glitter and glitz" of Aspen, there resides a core of folks who care about their open space lands, and have been committed to taking back some of the land from the exotic plant invasion, as the saying goes, "*one acre at a time.*"

**Perennial pepperweed** (also known as tall whitetop) is a long-lived, rhizomatous perennial that produces prolific tall, bushy sprouts from a large root system. It is frequently found in croplands, riparian areas and wetlands. It can be controlled by first removing standing dead stems from previous years at the flower bud growth stage, followed by application of chlorsulfuron herbicide. Removal of the standing dead material can be accomplished by mowing or by "chemical fallowing" with 2,4-D. Mowing twice is the recommended approach because it is more effective than a single mow or chemical fallow. The mowing or fallowing apparently changes the leaf architecture of the pepperweed, thereby greatly increasing the amount of

herbicide that falls on the leaves and, later, is translocated to the roots (Renz 1999). Changes in leaf architecture and removal of standing dead material as a result of mowing may also increase herbicide effectiveness in other weed species such as Canada thistle. Follow up by re-seeding the treated areas with a mixture of competitive, desirable grass species.

**Purple loosestrife** is a showy, long-lived rhizomatous perennial that aggressively colonizes wetlands and shorelines of lakes, streams and irrigation ditches. Integrated control should start with prevention, which could involve prohibiting the cultivation or distribution of this species along with *Lythrum virgatum* and their hybrids. Good control can be achieved with glyphosate, 2,4-D and triclopyr, but there are major limitations on the use of herbicides in wetlands. Remove seed stalks and burn them prior to applying herbicide if it is applied in the late bloom stage. A foliage flea beetle, *Galerucella pusilla*, has recently been found to be very effective at defoliating purple loosestrife in large stands. Therefore, a combination of herbicide treatment and introduction of the beetle may reduce purple loosestrife plants to acceptable levels (Debbie Eberts, pers. comm.). Small stands can be effectively removed by grubbing alone if efforts are persistent each year.

### **Purple loosestrife control in Colorado**

*Dave Weber is a biologist with the Colorado Division of Wildlife. Eliminating purple loosestrife from Colorado has been one of his missions since 1992.*

By 1993, three years after purple loosestrife was first seen in Colorado, the first serious control efforts were underway. Public agencies with purple loosestrife on their land had agreed to control the plant on their own property, and the Division of Wildlife took responsibility for controlling purple loosestrife growing on private property.

Dave Weber recalls the decision-making process that culminated in his belief that herbicides should be the primary means of combating the plant. He began by reading all he could on how to kill purple loosestrife. Through his research he determined that there were three ways to deal with the problem: hand digging/pulling individual plants, biocontrols and herbicides. Burning and mowing did not appear to be effective means of control. After considering the hand pulling option, Dave was convinced that there was too much purple loosestrife and not enough time or labor to effectively control a plant which would grow back if the root was not entirely removed. In addition, he was concerned that hand digging would result in disturbances favorable to the germination of purple loosestrife seeds already in the seed bank.

In 1993, biocontrols capable of surviving in Colorado were as yet unknown. Furthermore, Dave felt that in this situation, at the very beginning of an infestation, biocontrols were not the most suitable choice, and it was better to completely eradicate the infestation as quickly as possible. This left herbicides as the control method of choice.

Personnel were hired to search intensively along the stream corridors of the S. Platte River, Bear Creek and Clear Creek, where purple loosestrife was known. Private property owners were contacted for permission to treat purple loosestrife on their property with a combination of seedhead removal followed by herbicide spraying. The two-pronged attack on purple loosestrife was necessary because of the 20 year viability of seeds in the seed bank if allowed to mature. Virtually all landowners granted the DOW permission to treat the purple loosestrife on their land.

To date, the main herbicide used has been Rodeo®, a glyphosate herbicide that is used on mature plants. This herbicide is not selective, so care has to be taken to avoid unwanted "collateral damage". Aquatic 2,4-D, selective for broad leaf plants and for use before flowering, has been used as well, with mixed results.

Dave believes that the biggest mistake made in this control effort was not undertaking close monitoring of sites in the early years. However, since monitoring began 3 years ago it has become clear that progress is being made, and the amount of purple loosestrife has been “dramatically reduced at many sites”. He is personally most proud of the fact that not only has the amount of loosestrife been reduced at many sites, but the plant hasn’t spread much. “In 1993, billions of seeds were moving down the S. Platte River, threatening northeast Colorado wetlands. Today, very few seeds are moving downstream from Denver”.

**Russian knapweed** is a long-lived, rhizomatous perennial that sprouts prolifically from its deep root system and grows in riparian areas and other sites with elevated water tables. It can be controlled effectively with fall application of the herbicides clopyralid + 2,4-D, or picloram before plants have been exposed to a killing frost, followed by reseedling with a mixture of competitive plants the following spring (Chad Reid, pers. comm. Cindy Owsley, pers. comm.).

**Spotted knapweed** is a perennial weed that inhabits somewhat moist sites and reproduces solely from seeds. Integrated management involves proper grazing management and re-seeding depleted areas with a mixture of competitive grasses. Additional control methods include grazing with sheep or goats, prescribed burning, introduction of one or more biological control insects, and spraying with picloram. Brown et al. (1999) found that combinations of mowing and Tordon® herbicide or mowing and Curtail® herbicide provided better control than either treatment alone without damaging grass cover.

**Salt cedar, Russian olive, Siberian elm and crack willow** are small trees or shrubs that grow along rivers and around lakes at lower elevations. They can be controlled with a combination of cutting the plants then immediately applying triclopyr herbicide. Cut the stems as close to the ground as possible with a chain saw or a pair of double-action loppers. Apply herbicide within 30 seconds of cutting, concentrating the herbicide on the outer portion of the stump where the cambium (or growing) layer occurs. The cambium cells translocate the herbicide to the roots so that the entire plant is killed. Some people have found that the kill rate is highest in the fall, presumably because the plants are translocating material from the stems to the roots at this time of year. This approach works well for relatively small areas or for larger areas where these plants are scattered.

**Yellow starthistle** is a winter annual that is a major problem on crop and range land in California and the Pacific Northwest, where it is especially common in sagebrush steppe areas. It is not yet widespread in Colorado. Integrated management may involve combinations of proper livestock grazing management, herbicide application, biological control organisms, and re-seeding with competitive, desirable plant species. Seeding with competitive grass species has been shown to suppress yellow starthistle when combined with proper grazing management (Bill Burrows, pers. comm.). Cattle and sheep can be used as tools to invigorate desirable grass species and graze starthistle before spring arrives. A number of insects are available that primarily attack developing seeds, thereby reducing seed production. Picloram, as well as dicamba or 2,4-D (low volatile ester) provide control for as long as three years (Sheley et al. 1999). Recent studies in California indicate that prescribed burning can be very effective at killing yellow starthistle while not harming desirable plants (Hastings and DiTomaso 1996).

## A HYPOTHETICAL EXAMPLE

Fred Smith owns a section of land along a stream in western Colorado. He and his wife live on the ranch, and they both work in town. He leases his property to a neighbor who runs yearling cattle. The neighbor had suggested to Fred that he might want to spray the Canada thistle along the irrigation ditch and in the wetter parts of his pastures. Fred attended a weed awareness meeting organized by the CSU local agriculture extension agent. Fred found out that weeds could create many problems for him and potentially reduce the market value of his property. At the meeting, Fred picked up a copy of this weed management guide and looked it over when he returned home that evening. He concluded that he had better do something about the weeds on his ranch, so Fred asked the county weed supervisor to help him prepare a weed management plan for the property. Fred and the weed supervisor surveyed and mapped the weeds on the ranch. As a result of the survey, Fred had a map of his property that showed 15 infestations of five different noxious weed species. After conferring with the range conservationist and the county agent, Fred decided that his highest-priority weeds were Canada thistle and Dalmatian toadflax. He thought that Canada thistle was a major problem because it seemed to be expanding in his irrigated pastures which were the most valuable part of his ranch. He decided to control the thistle and toadflax immediately because he thought that the thistle was already causing significant economic loss and that the toadflax would soon be doing the same. In addition, Fred realized that controlling Canada thistle on his ditch banks would help prevent thistle seeds from infesting his pastures via irrigation water.

Fred read the profiles for Canada thistle and Dalmatian toadflax in the weed management guide and read more information he received about these plants from the county agent. They decided to control the Canada thistle infestations along the ditch bank by cutting the plants with a weed whip three times during the growing season, followed in August by spraying them with a formulation of glyphosate that could be used near water. The other infestations were in a cattle pasture. Here, Fred decided to spray the thistle plants with molasses twice during the growing season so the cattle would eat them readily, with follow-up spraying in the fall if the thistle canopy cover had not declined by at least  $\frac{1}{4}$  during the growing season. Fred hired a neighbor's boy to pull the toadflax plants twice during the growing season, once during flowering so they were easy to find (and so no new seeds would be produced), and once a month later to suppress resprouting plants.

In addition, Fred decided to survey his ranch once each year to look for new weed infestations. He decided to monitor the infestations by taking photographs of all of the infestations of Canada thistle and Dalmatian toadflax from permanent points on the day of the annual survey. Fred plans to look at previous years' pictures while he is taking the current year's pictures so he can make an instant evaluation of the success of his weed management actions. And last but not least, Fred and his lessee worked with the NRCS range conservationist and developed a grazing plan that they thought would increase the vigor of the pasture grasses and thereby help crowd out the weeds.

## PUTTING IT ALL TOGETHER

- ☒ Read the profiles in Appendix 4 beginning on page 117 for all the high-priority weed species that you identified for your property or management area. You may also wish to read additional material about these weed species.
- ☒ Determine the weaknesses of each weed species and find control measures to attack the weakness. Select appropriate control actions for each weed considering your local environmental conditions, cost, practicality, and potential damage to non-target organisms and the environment.
- ☒ Fill in the Weed Control section of your weed management plan outline.

Read the next chapter on monitoring and evaluation, and develop a plan which will enable you to make an informed assessment regarding the effectiveness of your weed control program.

### **Developing a Community-Based Integrated Weed Management Plan**

Heather Knight, *Laramie Foothills Land Steward, The Nature Conservancy*

Heather manages The Nature Conservancy's 1600 acre Phantom Canyon Preserve in Larimer County. In addition, she has management responsibilities on some of the 7,000 acres of nearby property protected by The Nature Conservancy via conservation easements.

Although weed management is a regular part of her work, and local infestations of yellow toadflax, leafy spurge, Russian and spotted knapweed and Canada thistle are of great concern, it was the rapid spread of Dalmatian toadflax in the North Fork of the Cache La Poudre watershed, even into undisturbed sites, that especially alarmed Heather.

Evidently, private property owners in the community were equally alarmed about the threat of weeds to the watershed of the North Fork of the Cache La Poudre River, and realized that if nothing was done, the problem would only worsen. They also recognized that no single group had sufficient resources to adequately address the problem. So, The Phantom Canyon Ranches Landowners Association (a group that collectively owns approximately 10,000 acres of land near the The Nature Conservancy preserve) approached The Nature Conservancy about joining forces in the fight against noxious weeds. Heather agreed, and a community-based cooperative weed management area in which members could share limited resources was formed.

Membership grew, and today, partners involved in the weed management cooperative include The Nature Conservancy, the Phantom Canyon Ranches Landowners Association, the North Poudre Irrigation Company, Colorado Division of Wildlife, US Forest Service, Colorado State Forest Service, C.S.U. Maxwell Ranch, Abbey of St. Walburga, the Western Governors Association and several other private landowners.

In the year following formation of the collective, the focus was planning. Members visited neighbor properties to help set priorities and gain new perspectives; they took weed tours and learned to identify weeds, discussed realistic goals and objectives, and set the agenda for the second year. The plan for the second year is to map weeds, conduct training workshops in the community including training in mapping and writing management plans, and finally, to write management plans for all of the properties across the

watershed.

Ultimately, the plan is to integrate all the plans into one master plan that will direct how the cooperative will most efficiently use its resources across the watershed without regard to managing weeds across boundaries. The final management plan has not yet been created, but the plan is to creatively use as many techniques as possible and to devise alternative strategies to deal with variables including weather, equipment availability and presence or absence of other resources. The cooperative will likely use handpulling, chopping, selective herbicide application, and biocontrols. The cooperative is also committed to the reintroduction of ecological processes that will help maintain the health of natural communities and will increase the competitive advantage of native species. As such, the use of prescribed fire and grazing will likely be integrated into the final management plan.

### **Developing a Habitat-Based Integrated Weed Management Plan**

Laurie Deiter, City of Boulder Open Space Department

Laurie is the IPM Coordinator for City of Boulder Open Space lands, which encompass about 28,000 acres in a variety of habitat types, including cropland, forest, shrubland, grasslands, and riparian/floodplain areas. In the process of developing an integrated plan for Open Space lands, she has decided to focus her weed management planning on prioritization and control by habitat type.

"I think this approach makes a lot of sense. Limited weed resources require land managers to decide which weed species and infestations to treat. Weed species need to be ranked according to abundance, invasiveness/aggressiveness, reproductive potential, threats to open space values (i.e. rare plants/wildlife, recreation), feasibility of control, etc. Then you have to rank according to where they are found, although this may not be solely by habitat type. Examples of infestations that may be given higher priority are those occurring in or threatening rare plant/animal habitat or unique and sensitive plant communities, small but new infestations of a highly invasive weed, areas recently treated, riparian or recreational corridors, and so on. By ranking according to species *and* their habitat, you get a better perspective on what you have where and which areas should be your primary focus. Control techniques often must occur at the same time of year for the different weed species and it is up to the land manager to decide where to best spend their time as well as that of volunteer and seasonal help. This way of prioritizing also helps you gauge where money is going and if there is a need for more.

It is likely that habitat types will be incorporated into our planning primarily with the best management practices approach and by focusing what should and should not happen in a specific habitat. I think one's approach to weed management should vary according to the habitat, the individual weed species and reasons for their presence, and also according to the management tools that are available. Fire can and should be used as a tool in many habitats, some areas more often than others. Animals may be a consideration in certain habitats at certain times of year. In our riparian areas chemicals are used as a last resort and when we use herbicide in those areas, we then try to use a wick/sponge applicator. Riparian/floodplain areas are particularly challenging because of the presence of Threatened and Endangered species and surrounding agricultural practices. Control techniques are often not prescribed at the optimum time because of these other influences. I expect to see a step by step thought process for control based upon what habitat you are in and what you know about that particular area.

I hope that this approach will produce plans that are well defined and serve as guides for what we should be doing to control a weed species while at the same time being conscious of the surrounding vegetation and animals in that particular habitat. This method can be limited by the control options available to land managers, but Boulder Open Space is lucky to have the budget and resources that we do. We try to manage for so many different things that we need to be inventive, integrated, and particular in our weed management."

*Adapted and reprinted with permission from an article that originally appeared in the newsletter of the Central Rockies Chapter of the Society for Ecological Restoration.*

## Checklist for herbicide selection

Lisa Tasker and Michael Craig

Weeds are obviously one of the variables that can have enormous impact in the success or failure of a restoration project or management goals. Although there are numerous considerations in restoring or maintaining a healthy plant community, the ability of many weedy plant species to drastically affect the normal ecological functioning of an area is a formidable obstacle. The following discussion is for the restorationist or manager who has decided to use an herbicide. The intent is to walk the reader through an example of the thought process needed to choose the most appropriate herbicide for a particular weed problem.

The importance of a visit to your county weed extension agent cannot be over emphasized. If you have in fact decided to use an herbicide for weed control on your project, such a trip (or trips) is mandatory. This article is in no way meant to act as a substitute for the establishment of this crucial connection

Before reaching the decision to use an herbicide, the restorationist or land manager should have already investigated all of the weed control strategies and philosophies of Integrated Weed Management or IWM. This is not an article about IWM, but quick mention of some of IWM's philosophy and its multi-pronged strategies are important to note. The basic message of IWM is a plea to consider carefully all the strategies available for tackling weed problems and never to have a myopic focus on herbicides alone. Using IWM means the decision to use an herbicide for your weed problem is made *after* contemplating multiple alternatives (such as mowing, pulling, burning, etc.) and having practiced as many preventive measures as possible.

Even when other control methods have been considered, there often comes a time in IWM when you may consider the use of an herbicide. This can be a difficult choice, but it could make the difference in whether or not the desired outcome is reached in a project. If you have decided to use an herbicide as a tool in your IWM plan, then you need to make several educated decisions in order to decide which herbicide to use, as well as how and when to use it.

The following is a checklist (albeit not necessarily complete) of some crucial questions to answer as you begin to look for the right herbicide for your weed challenge. If you sit down and answer all the questions and then visit an extension office or weed professional, you will probably save yourself and the county extension agent a great deal of time. In Colorado, don't forget that while you are going through this time consuming decision making process, your weeds may be going to seed. For many weed species, it's the law that you keep this from happening.

*1. Learn the correct identification of the weed(s).* Is it a broadleaf plant or a graminoid? Is it a perennial or an annual? Learn which plant family it belongs to and identify it to species. Some herbicides are family specific.

*2. What is the growth rate of the plant in your area?*

*3. At the time you are able to spray, what is the growth stage of the plant? Better yet, what growth stage must the plant be for your chosen herbicide to be effective?*

*4. What level of control do you desire?* Eradication is rarely a realistic option. "Weed management" means you know you'll be able to live with some weeds or perhaps you are more realistic and understand you WILL be living with some weeds.

*5. Where are the weeds located?* Are they in an upland community or in a wetland or riparian area?

*6. What is the hydrology of the area?*

*7. Describe the soils.* Are they permeable, or close to a water table? Is soil pH a concern? Some herbicides are very soil pH sensitive.

*8. What plants do you want to keep?*

*9. What is the land use of the site now, and what will it be in the future?* Is it rangeland, industrial, farmland, prairie, shrubland, forest, etc.?

*10. Are you a licensed applicator or can you hire someone who is?* If not, you cannot consider some herbicides such as picloram (Tordon), a restricted use pesticide (RUP).

*11. Are you spot spraying or are you broadcast spraying?* This will affect the overall potency of the product you choose. If you are spot spraying you may use a higher octane, so to speak, than if you use a broadcast application.

*12. Can you use a long-term approach or do you feel forced to use a short-term approach?*

*13. What is your budget (how much money can you spend!)? What size is your project?*

*14. What are the hazards involved in using a particular herbicide?* How much personal protective equipment (PPE) do you need for spraying?

Now let's try applying just a few of these questions to a hypothetical restoration project to illustrate the complexity of this decision-making process.

Consider the example of a ten-acre, short grass prairie site with about one acre along a small stream. Begin by making a list of what is going on in the area. There are numerous established trees along the stream and some shrubs scattered throughout the remaining nine acres. Prior to the restoration, the site has Canada thistle, *Breia arvensis* (*Cirsium arvense*), at medium densities in patches over half of the ten acres. The elevation is 5000 feet and the annual precipitation is 18 inches, which translates into healthy thistles. The majority of the site is upland with silt and clay dominant soils. The water table is more than twenty feet deep in these areas. The transition from the upland down to the riparian area is a steep slope that ends in the riparian zone. The riparian area has cobbly and sandy soils and the water table is at the surface to 3 feet deep. Due to management constraints the site can only be sprayed in the spring and fall. The level of control desired is no less than 90% (you dream of 100%).

Your next task is to identify herbicides that may be appropriate for the job. You'll find there are more than a dozen herbicides labeled for use on Canada thistle. For this example let's consider some of the above questions for five of the more commonly used herbicides labeled for this species of plant. We'll examine picloram (Tordon) clopyralid (Transline), chlorsulfuron a (Telar), glyphosate (Roundup), and an ester or amine of 2,4-Dichlorophenoxyacetic acid, aquatic label (2,4-D). The use of trade names in no way implies that we are preferentially suggesting or advertising any specific brands of herbicides. We use the trade names merely for ease of recognition for the reader.

Going back to our example, let's start with question 3. Since we plan to spray only in the spring and/or fall we want to know what the labels for each herbicide recommend for application timing. The first thing to do is to get copies of all five herbicide labels because "the label is the law". Compiling this information may also require searching further than the label!

*Question 3: growth stage required for an herbicide to be effective*

Telar is most effective from late spring to early summer, prior to the time that Canada thistle sets seed. Telar is less effective when weeds are hardened off after drought stress or cold weather, so fall application may be too chancy. Tordon has residual effect in the soil so it can be taken up by the roots or the leaves, which makes it suitable for early spring and early fall treatments. Transline must be applied during active growth. The plant must be allowed to grow awhile or be post-emergent to meet this requirement, so too early in the spring won't be effective. 2,4-D and Roundup are effective for a relatively short period of time after being sprayed. This means you need to take care not to spray too early in the season or the plant may have enough stored energy to recover. The weed could outlast the herbicide's effect and rebound to become a problem later in the season. Timing of treatment and the growth stage of the plant, together, are absolutely critical for success in using an herbicide.

*Questions 5, 6 and 7: weed location, soil and hydrology information.*

These questions are crucial to the selection of these herbicides. If you purchase 2,4-D that has the aquatic label (note: not all formulations of 2,4-D are labeled for aquatic use) then you may use it according to label on Canada thistle in the riparian area. Another choice for the riparian area may be to use Rodeo, the aquatic counterpart to Roundup. This herbicide, like Roundup, is nonselective to most plants so if you want to save any existing plants (question 8) you had better be using a spot application or else considering a different herbicide.

The other herbicides listed are best limited to areas away from water. The upland area would probably be a safer bet for Tordon, Telar, and Transline with an untreated buffer zone near the transition zone to the riparian area. The clay and silty soils are important factors that make the upland area safer for the use of these herbicides. The small particle size of clays and silts bind to the herbicide molecules more effectively lowering infiltration rates. It is more likely that the water table will remain out of the reach of the herbicide.

*Question 8: Plants to be saved from herbicide impacts.*

This is the million-dollar question, which plants would you like to see survive this chemical onslaught? Transline is most effective on the Aster, Legume, and Buckwheat families, which makes it very attractive in many situations. Roundup is primarily non-selective and can potentially kill or injure most plant species. Telar, Tordon, and 2,4-D are all broadleaf selective herbicides that are not supposed to kill grasses when used at the recommended rates and appropriate growth stages of non-target plants. If you would like to kill the smooth brome, *Bromopsis inermis*, (*Bromus inermis*) growing with the Canada thistle these herbicides won't do the trick. If saving native grasses growing with the thistle is a goal, then Telar, Tordon, and 2,4-D are possibilities.

Think about herbicide impact on non-target forbs as well. This depends on which forbs are present, the time of year of application, and the rate of herbicide applied. Some forb species go dormant in late summer and early fall while Canada thistle continues to photosynthesize until the ground freezes. Fall provides a great window for management of Canada thistle. Desirable forb species that have gone dormant will be spared, and only the thistle will be affected by herbicide application.

Note that Tordon is very active on woody species and can damage or cause injury to many trees and shrubs. In our example, there are scattered shrubs in the upland and trees along the riparian corridor. Clearly Tordon would not be a good choice if you want to keep existing woody species while attempting to control the weeds beneath them. Tordon also remains chemically active in the soil for a longer time period. If you planned to install trees on the site immediately after spraying, Tordon again is not a good choice. If you are spraying near existing shrubs or trees, these plants may be killed or injured by Tordon. But if you plan on waiting a season to install any new seeds or plants after your herbicide application, Tordon is still an option.

*And so on through the rest of the questions.*

Obviously the decision to use an herbicide, and the choice of which chemical to use is a lengthy, slowly evolving process. You must examine each question and, through a process of elimination, find the herbicide that best fits your project. Then you look at the price tag and hope it fits your budget. If you find that a restricted use herbicide best meets your needs, you may find yourself looking for a qualified applicator as well.

Since how you answer each of the above questions is crucial to your final decision on an herbicide, **save the above list**. If a weed challenge presents itself, pull out your questions, answer them thoroughly, and make an appointment with your county extension agent. He or she will probably be glad that you saved them a step by asking and answering most of their questions in advance. In addition to helping with herbicide selection, county extension agents can keep you up-to-date on the latest label changes and herbicide name changes. The more effort you put into your selection and implementation process, the more likely it is that your herbicide choice will help you reach your management objectives.

### **A Working Education in Weed Management**

Heather Poe, *Roxborough State Park Ranger*

I'm in charge of noxious weed management at Roxborough State Park in Douglas County, Colorado. Like many jobs, mine requires me to fulfill many roles. When I started, Cecilia Travis, then a seasonal ranger, convinced me that weed management would be one of the most important. Being a complete novice, I set out to learn all about weeds. I found *Weeds of the West* and the Douglas County weed plan to be good resources, but even more helpful were the weed managers I met through the Colorado Weed Network.

Historic weed management at Roxborough had focused on musk and Canada thistle, with some hand pulling of diffuse knapweed by volunteers. At first I had difficulty distinguishing between the species of thistle, so I learned what our one native species looked like and decided the rest were fair game. I was familiar with leafy spurge but didn't find any at the park. I learned about more weed species by comparing the park's plant list with the State Weed List, using *Weeds of the West* to get a search image, and asking people familiar with the park if they knew of infestations. I decided to target the diffuse knapweed and various thistles while looking for infestations of other weed species. I knew if I found infestations of the "bad boys" like leafy spurge, they would take priority.

The Douglas County weed plan told me that a bio-control for musk thistle was well established throughout the area. Cecilia and I also found larvae in the seed heads of diffuse knapweed, so we knew we had some bio-control there. I had read that there was not an effective bio-control for Canada thistle available. Roxborough had a herbicide budget that would pretty much cover only treating the roadsides. Since grading and snow plowing constantly disturb the roadsides, and vehicles are a vector for seed dispersal, I thought this was a good use of the herbicide budget. Our herbicide budget was not likely to increase, so I needed to look at other ways to increase our control efforts.

In the past, summer youth crews had been assigned to pull and dig out Scotch and musk thistle. Cecilia had also led groups of students in weed pulls. A few of Roxborough's dedicated Volunteer Naturalists had also pulled weeds. When the opportunity came to apply for funds to support volunteer projects, I applied for and was awarded a grant to start Roxborough's Weed Warriors program, modeled after our successful trail volunteer program. We planned weekly Weed Warriors days and began advertising our Weed Warrior volunteer opportunities through VOC, Metro Volunteers, and the park newsletter.

My sources told me that weed control efforts directed toward scattered or light infestations yield the most "bang for the buck." I thought that hand pulling, being a highly selective technique, would be perfect for light infestations in areas with desirable vegetation; heavy infestations would be better handled with herbicide if we ever got additional funding. Even though hand pulling is not recommended in the literature as a control method for Canada thistle, Weed Warriors would pull them because many patches were in sensitive areas I was extremely reluctant to treat with any other method. I also thought that reducing seed production and depleting root reserves couldn't hurt. Musk thistle would be a very low priority once seed heads formed because of the well-established bio-control.

The first summer I learned that weed philosophy is of little meaning when people want to kill something. All but the most experienced weeders get frustrated searching for a knapweed in a haystack. Even experienced weeders will not willingly bypass a large, heavy weed patch. Groups of a certain age and number are as highly selective as locusts, and teenage boys will go for the largest mature thistles every time, no matter how low a priority they are.

Now I use experienced small groups to take on the lightest infestations and direct the largest teenage groups towards our "Armageddon meadows". We hit the large thistles early, and I don't worry too much if a few weevils get killed in our high priority areas. Hand pulling Canada thistle does take many repeat visits, but some light patches have been eliminated and the teenagers have reduced an Armageddon

meadow (90-95% Canada thistle) to a merely heavy patch (50% Canada thistle with some desirable plants moving in). Roxborough Weed Warriors have contributed 2,000 hours of hand pulling and cutting in 3 years. The program has also served as a basis for our educational efforts, inspiring questions from park visitors who see our volunteers or the control sites. While many volunteers only come one time, others come back regularly and serve as weed control ambassadors to their homeowners associations, neighbors, and classrooms.

## VIII.

# MONITORING AND EVALUATION

Monitoring is an essential component of a weed control program. Monitoring is the repeated collection and analysis of information to evaluate progress in meeting resource management objectives (Elzinga et al. 1998). Periodic observation of the weeds being managed is necessary to evaluate the effectiveness of a weed control program. Monitoring saves money by helping you find out what is working and what is not. If management objectives are not being met, weed control actions need to be modified. Without some type of monitoring, there is no way of knowing whether control actions are contributing to the fulfillment of management objectives. If control actions are not working, there is no reason to continue them.

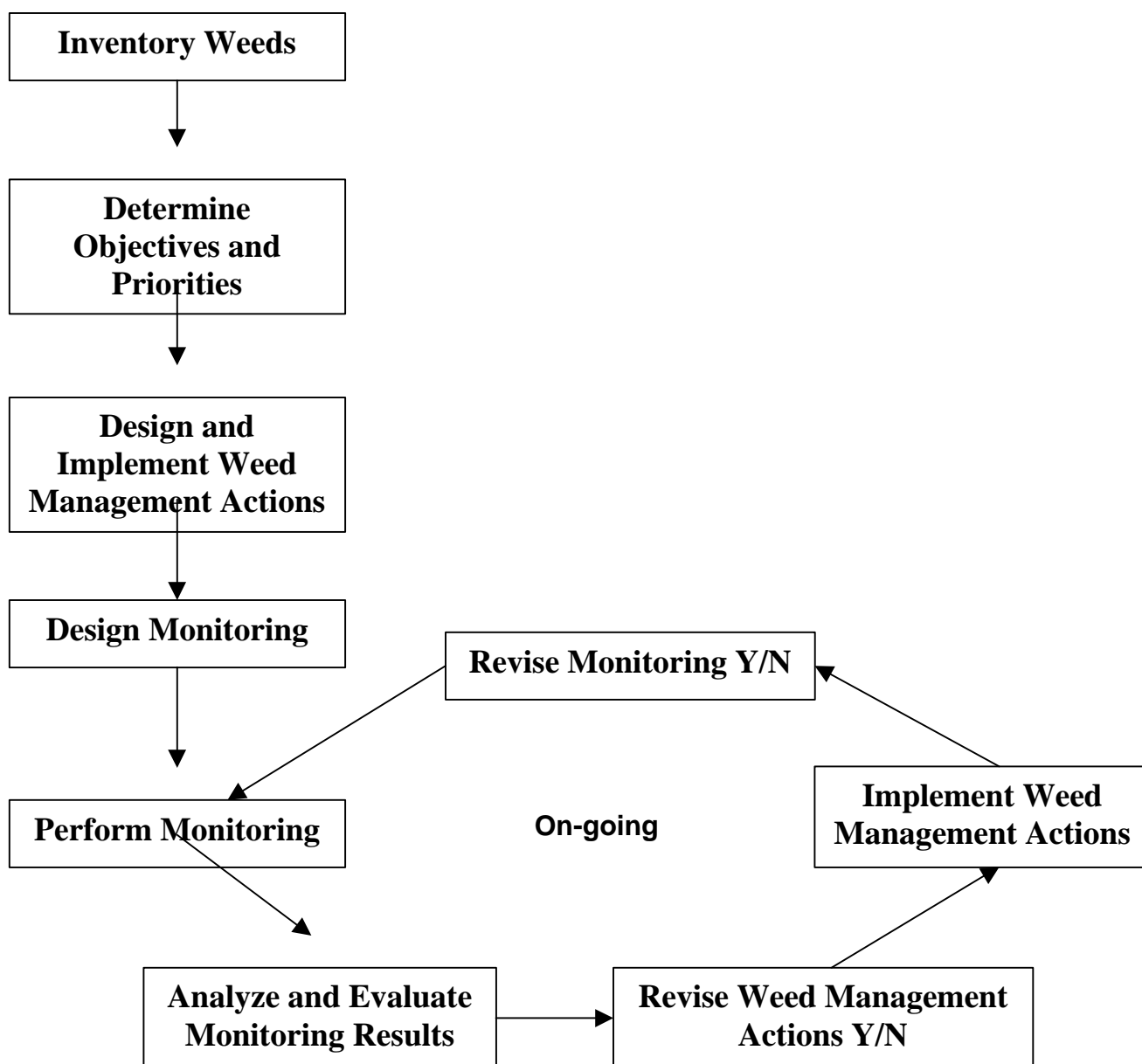
There are several important factors to keep in mind with regard to the formation of a monitoring strategy.

- If your monitoring program is simple and straightforward you are more likely to complete the monitoring and learn from it. The effort you invest in monitoring depends on what could happen if your management actions are not working or are counter productive. A higher risk of failure means more effort should go toward monitoring. For example, using high densities of livestock to control weeds requires close and frequent attention to the forage available to avoid overgrazing. Also, eradicating high-priority weed species may require more monitoring than the suppression of low-priority species because eradication of high-priority species will be a much more important goal.
- Monitoring, like weed control, is an ongoing process. Although the information gathered in the early days of a monitoring study is certainly valuable, its value is enhanced by comparison with every future piece of data. Even a simple monitoring program may not yield easily interpreted results with the first few repetitions. However, the likelihood of detecting useful trends increases with each year of monitoring.
- One of the limitations of most monitoring programs is their inability to determine cause-and-effect. Although monitoring data can tell you if a weed species decreased in abundance, the data cannot definitely tell you if your weed control actions *caused* the decline. It is possible that a decline in weed abundance would have happened anyway, due to unfavorable weather or other factors. Determining cause-and-effect requires replicated, controlled experiments where all relevant factors are closely controlled except for one that is varied. Such experimentation is normally performed by university, government and industry researchers, and is not usually practical for private landowners or public land managers. However, there are some situations where land managers could conduct experiments; for example, testing whether two weed treatments differ in their ability to control a weed species. Anyone who wishes to conduct more complex monitoring or experiments should read *Measuring and*

*Monitoring Plant Populations*, a recent, comprehensive reference available from the Bureau of Land Management, National Service Center, Denver Federal Center, PO Box 25047, Denver, CO 80225-0047.

## STEPS IN A MONITORING PROGRAM

Monitoring is a structured approach to collecting and analyzing resource information. It can be an informal process or it can be highly formal. The steps of a monitoring program and the relationship of monitoring to the overall weed management are shown in the figure below.



## SETTING MONITORING PRIORITIES

Using your previously identified high-priority weed species and infestations, decide which of the species and infestations you will monitor, based on the number of weed species and weed infestations and the resources at your disposal. In addition, you need to decide how intensively to monitor the species and infestations, that is, how much effort you are willing to devote to monitoring.

*We recommend that you establish a minimal level of monitoring for each high-priority weed species and high-priority weed infestation in each of your weed management units. In addition, you should establish a system of recording and tracking herbicide applications and biocontrol releases.*

We suggest that you monitor at least:

- Two sites where each high-priority weed species occurs; and
- One high-priority weed patch.

There will probably be some overlap in the above categories that will reduce your monitoring work. For example, if one of your high-priority weed species is Canada thistle and two of your high-priority weed infestations are patches of Canada thistle, monitoring those two patches would satisfy your minimal monitoring needs for Canada thistle.

## DESIGNING MONITORING ACTIONS

The challenge of monitoring is to find a balance between the time and money spent monitoring and the value of the information you expect to obtain from monitoring. There is a direct relationship in monitoring between the time required to collect information and your ability to determine if your weed control objectives are being met. If you spend less time collecting and analyzing monitoring data, you will be less able to evaluate your weed management actions. Conversely, if you spend more time and money monitoring, you will have a better idea if you are meeting weed management objectives.

The methods used to monitor the high-priority weed species and infestations depend on weed management objectives. Thus, the complexity of monitoring depends on what you need to know to determine if weed management objectives are being met. Examples of several weed management objectives and monitoring methodologies are presented below. Note that many of the monitoring actions are very simple and their “analysis” is largely self-evident. Keep monitoring actions as simple as possible to increase the likelihood that you will actually monitor your weeds and understand the results of the monitoring. Most private landowners will not need to conduct complicated monitoring programs involving formal statistical tests, and will not need to monitor as many plots. Public land managers and others who must keep detailed records in support of management decisions should consult *Measuring and Monitoring Plant Populations* (see above) and other basic statistical reference books as an aid to monitoring plan design.

- ☒ Review your weed management objectives to see if you can re-word them so they can be evaluated with simple monitoring actions. Make sure your objectives specify time, numbers and location.

Examples of weed management objectives and associated monitoring actions. Monitoring actions follow directly from weed management objectives. The management actions below would be initiated if monitoring shows that the weed management objective is not being met.

**Weed Management Objective:** Reduce the infestation of Russian knapweed adjacent to the pond to no more than fifteen patches with patches no bigger than ten feet in diameter within five years.

**Monitoring Action:** Walk around the pond once each August and count the number of Russian knapweed patches; note any patches that are larger than ten feet in diameter.

**Management Action:** Schedule follow-up treatment.

**Weed Management Objective:** Eliminate seed production of Canada thistle plants along the Walker Ditch every year for the next five years.

**Monitoring Action:** Walk along the ditch once in June, July and in August and check for Canada thistle flowers and seed heads; note the locations of any seed heads.

**Management Action:** Schedule follow-up treatment if control cannot be accomplished immediately.

**Weed Management Objective:** Eradicate Dalmatian toadflax on the property within five years.

**Monitoring Action:** Walk over the property in June and August each year (when the toadflax plants are likely to be in flower) and look for toadflax plants; note the locations of any plants found.

**Management Action:** Pull or spray any flowering or fruiting plants found. Dispose of flowering parts properly.

**Weed Management Objective:** Eradicate the patch of leafy spurge by the front gate by the year 2005.

**Monitoring Action:** Check the patch in June and in September and note the presence of any living leafy spurge stems.

**Management Action:** Schedule follow-up treatment immediately to eliminate year's seed production and to kill adult plants.

**Weed Management Objective:** Reduce the density of reproductive diffuse knapweed plants to no more than three plants per square yard in the grassland portion of the preserve over the next five years.

**Monitoring Action:** Walk around the grassland area and count the number of reproductive diffuse knapweed plants within thirty 4 foot by 2.5 foot (1 square yard) randomly located plots.

**Management Action:** Schedule follow-up treatment.

**Weed Management Objective:** Reduce the abundance of purple loosestrife along Muddy Creek to insignificance by the year 2000.

**Monitoring Action:** Walk the length of Muddy Creek on the property every July (when purple loosestrife plants are flowering) and search for purple loosestrife plants; note the locations of any plants found.

**Management Action:** Clip all seed heads and cut stem at base of plant. Dispose of clipped seed heads properly.

## Written Records

The most basic form of monitoring consists of taking careful notes of :

1. Sizes of the high-priority infestations and the general abundance of the weeds in those infestations.
2. General extent and abundance of the high-priority weed species that are not found in the high-priority infestations.

For weed management objectives that specify eradicating a patch of weeds, the only monitoring required is to note whether the patch is present or not. A few sentences in a field notebook will be sufficient documentation. Consider buying a field book of the type that surveyors use. These books are very sturdy and will last for years. A very simple way to monitor weeds is to use a tape recorder to record observations while you drive, ride or walk around your property. You can transcribe the tapes during the winter when you are not as busy.

## Photographic Records

Photographs can be extremely useful in documenting changes in weeds over time, especially if they are taken from permanent locations (called photo points) each time. Photographs work best for monitoring weed species which can be easily distinguished from other plants during flowering. Examples of these types of species include leafy spurge, purple loosestrife, low white top, perennial pepperweed, Dalmatian and yellow toadflax, oxeye daisy, and spotted knapweed.

Photo points can be established adjacent to high-priority weed infestations since these sites are likely to be relatively small. Carefully select the location of the photo point so that all or nearly all of the area can be seen from the photo point. Mark the location of the photo point with a permanent marker to enable it to be relocated for subsequent monitoring photographs. Some convenient permanent markers include metal fence posts or 2-foot lengths of 5/8-inch rebar driven into the ground and covered with an aluminum cap to prevent injury to people and livestock. Sturdy red 18" plastic stakes (Plastake®) are also available from mail order outlets such as Ben Meadows or Forestry Suppliers (see Appendix 1, page 87).

Take photographs when the target weed is most visible, usually during the period of peak flowering. Try to include obvious background features such as fences, trees, cliffs, and distant mountains as an aid to repeating the photograph with the same scene every year. Carry prints of last year's photographs mounted in plastic sleeves in the field, to help you frame the scenes correctly and to provide instant visual comparisons of weed abundance. One or more photographs may be taken at each photo point depending on the situation. Use a 35-mm camera with color film. Note the locations of the photo points on your weed map with an arrow showing the direction of the photograph, and give each point a unique number. Keep a log of pictures taken (possibly in the field notebook), matching the number of the exposure with the number of the photo point and the scene being photographed. Write the photo point number and the date on each developed photograph or slide as soon as you receive them otherwise you may forget to do it. Cameras which automatically include the date in the picture are handy for photo monitoring.

## Electronic Records

Infestation acreage and treatments can be recorded in a GIS, or in spreadsheet form. This would allow graphical tracking of results over time.

## ESTIMATING WEED ABUNDANCE

Occasionally you may need to estimate weed abundance in order to evaluate a particular weed management objective. Two standard measures of weed abundance are *plant density* and *plant cover*. Use one or the other of these methods. Both methods involve counting or estimating the numbers of plants which fall within a randomly selected small plot or “quadrat.” Randomized sampling, as described below, enables the data to be analyzed with statistical tests. Monitors who do not intend to use such tests will not need to sample as many plots.

### Weed density

Plant density is the number of plants (or parts of plants) per unit area of ground surface. Density is most appropriate for non-rhizomatous plants that do not spread from underground stems or roots. For example, the density of common mullein can be expressed as the number of mullein plants per square yard. The density of rhizomatous plants would be the number of plant stems per unit area of ground surface; for example, the number of Russian knapweed stems per square yard of ground surface. In the case of rhizomatous plants, such counts do not usually reflect the number of individual plants. Often density refers to the number of flowering plants or stems, although established non-flowering plants may be included if desired. Be sure to note on the data sheet whether you are including only reproductive or all established plants in your plant abundance estimates.

Density can be estimated in two ways:

- Counting the number of plants of the target weed species in a plot.
- Visual estimates of density, if numbers are too high to make counting practical.

### Counting weed plants to estimate density

- Determine the weed species whose density you want to estimate and the area covered by the weed management objective. For high-priority weed patches, the area would be the patch. For a larger area infested by a high-priority weed species, it would be the mapped area where the weed occurs in a weed management unit.
- Randomly select a spot to begin to collect density data. This can be done by overlaying a grid on the aerial photo, or using measuring tapes laid at right angles on the ground, and then using a random number generator to select coordinates. Randomly selected plots can be permanently marked, or new randomly located plots can be selected each time monitoring is performed. This choice will affect the type of statistical analysis used.
- At each spot, orient a plot frame with the long axis of the frame running north-south. We recommend using a plot frame that is 2 feet by 4.5 feet because it covers one square yard of ground surface and because rectangular plots are more efficient than other shapes. One can make an inexpensive plot frame by purchasing a 20-foot length of ½ diameter white PVC pipe and four elbow joints. Use a hacksaw to cut the pipe into two pieces each 55 inches long and two

- pieces each 23 inches long. Fit the pieces together and measure the size of the resulting frame (inner dimensions). Disassemble the frame and trim the pieces of pipe if needed. When the pieces are cut to the proper length, assemble the frame, check the inside dimensions, and glue the frame pieces together.
- Count the number of established weed plants that are rooted within the plot frame and record this number on a data sheet. Do not count seedlings but note their presence on the data sheet. See Appendix 7 (page 307) for sample data sheets. Repeat the process of randomly selecting sampling locations 29 more times to sample a total of 30 spots, if you will be performing statistical analysis on the data. If the patch is small (less than 100 feet by 100 feet in size), 15 samples should give you an adequate picture of the infestation.
- Back at the office or at home, calculate the average plant density by adding up all the density data and dividing by 30 (or 15). Computer spreadsheets can do this very easily.

### Visually estimating weed density

- Follow the steps presented in the first three bulleted items in the box above.
- Instead of counting the number of weed plants in each frame, estimate the number of weed plants according to the categories below:

<u>Category</u>	<u>Number of target weed plants in each 2' x 4.5' plot</u>	<u>Symbol</u>
Absent	0	A
Scattered	1	S
Light	2-5	L
Moderate	6-9	M
Heavy	10 or more	H

Enter the symbol (A, S, L, M, or H) for the appropriate category on the data sheet.

- Repeat this process of randomly selecting sampling locations 29 more times to sample a total of 30 spots, if you will be performing statistical analysis on the data.
- Back at the office, count the number of plots that fell in each density category and record these numbers on your data sheet.

### Weed cover

Plant cover refers to the proportion of ground surface (usually expressed as a percent, such as 50%) that is hidden by the target species when the area is viewed from directly overhead. A high percent cover of a species is roughly correlated with high abundance of that species, although the size of the individual plants also has an effect. Plant cover can be estimated visually as described below.

Your ability to estimate vegetation cover precisely improves if you compare samples of known cover to the vegetation whose cover you are estimating in the field. You can make samples that are 25%, 50% and 75% cover using three sheets of white and three sheets of dark paper. The sheets of light and dark paper need to be the same size. For the 25% cover sample, fold a sheet of dark paper in to fourths. Cut one of the fourths from the larger sheet. Then cut the one-fourth portion into smaller shapes that resemble the outlines of plants.

Arrange these pieces of dark paper on one of the pieces of white paper so as to resemble plants and glue them in place. You can make the 50% and 75% cover samples by using one-half and three-quarters, respectively, of separate sheets of dark paper and following the procedure above. You can photocopy the sheets and take them into the field with you. You can laminate them to increase their durability. When you stand over a plot, lay the 25%, 50% and 75% samples on the ground next to the plot and compare the cover of the dark shapes to the cover of the target weed species. For example, if the cover of the target weed species in the plot appears to be less than the cover of the 25% sample, you would record cover category L (Light). Or if the cover of the weed seems to be greater than that of the 75% sample you would record cover category E (Extreme) for that plot.

### Visually estimating weed cover

- Determine the weed species whose cover you want to estimate and the area covered by the weed management objective. For high-priority weed patches, the area would be the patch. If it is a larger area infested by a high-priority weed species, it would be the mapped area where the weed occurs in a weed management unit.
- Randomly select a spot to begin to collect cover data. This can be done by overlaying a grid on the arial photo, or using measuring tapes laid at right angles on the ground, and then using a random number generator to select coordinates. Randomly selected plots can be permanently marked, or new randomly located plots can be selected each time monitoring is performed. This choice will affect the type of statistical analysis used.
- At the spot, lay the plot frame on the ground without looking directly at the ground. You do not want to bias the selection of the precise plot location. We recommend using a plot frame that is 2 feet by 4.5 feet because it covers one square yard of ground surface and because rectangular plots are more efficient than other shapes.
- Standing at the middle of the long axis of the plot and looking straight down toward the ground, estimate the cover of the target weed species. You may have to move back and forth to obtain a clear view of the entire plot. Estimate weed density according to the following categories:

<u>Category</u>	<u>Estimated cover of the target weed species in each plot</u>	<u>Symbol</u>
Absent	0	A
Light	1 % - 25%	L
Moderate	25% - 50%	M
Heavy	50% - 75%	H
Extreme	75% - 100%	E

It is best to record your initial impression of weed cover, rather than spending lots of time deciding which cover category best describes the plot. Record the appropriate symbol (A, L, M, H, or E) on your data sheet.

- Repeat this process of randomly selecting sampling locations 29 more times to sample a total of 30 spots, if you will be performing statistical analysis on the data.

☒ Devise one appropriate monitoring action for each one of your weed management objectives and write this action in the weed management plan outline.

## TEST MONITORING ACTIONS

Monitoring actions should be tested to see if they will really work in the field. Often ideas that seemed great in the office don't work very well in the field. Testing your monitoring methods before embarking on your monitoring program can save time and money in the long run. It is much easier to redesign a monitoring protocol after a failed test than to redesign the program half way through the monitoring period. Questions to consider during the pilot phase of a monitoring program include:

- Will the data collection methods really work in the field? You may discover that it is not practical to count certain species to estimate density, or that thick vegetation prevents sampling plots from being laid out uniformly. Permanently marked plots may not be easy to relocate after all. Such problems need to be identified and corrected before you commit large amounts of time and resources to a monitoring program.
- Is the cost and time of performing monitoring acceptable? You may discover that it takes too long to collect the data called for in your original monitoring design, or that monitoring actions are too expensive. It is important to design a monitoring program that you can afford to implement. A less ambitious program is better than none at all.
- Will the observations allow you to detect changes? Given the constraints of field methods, time and money, the bottom line is whether or not the monitoring will allow you to evaluate the effectiveness of weed control actions.

Keep in mind that the usefulness of monitoring arises from its repeated nature. You must continue to monitor to detect changes which will affect your management decisions.

## IMPLEMENT MONITORING

The most critical step in any monitoring program is to begin doing it. If you don't do the monitoring, you will not be able to determine if you are meeting your weed management objectives. Monitoring will save you money by insuring that your control efforts are as effective as possible. After you begin monitoring, follow the cycle shown at the bottom of the figure on page 74:

1. Perform monitoring by collecting field data according to plan.
2. Analyze and evaluate monitoring results immediately after each data collection.
3. Determine whether weed management actions need to be revised, given the results of monitoring analysis.
4. Implement weed management actions again, revise as necessary.
5. Evaluate monitoring actions (analyze data), revise as necessary.
6. Begin the cycle again.

Whenever possible, share the results of your monitoring with other weed managers, and help to build a base of weed control knowledge that others can use in the fight against noxious weeds.

Don't over-respond to your monitoring results. You may need to give a treatment method more than one year of trial. Check with other land managers in your area to see if it was a particularly "good" year for your weed species.

Don't forget to include repeated reconnaissance for new weed species and infestations in your monitoring program.

# CONCLUSION

Now it is time to prepare a weed management plan. The sooner you begin to apply what you have learned, the sooner you can benefit from it. As you prepare your plan, please remember these five key points:

- **Ask for help.** Obviously, there are many resources available to you. Get to know your county weed supervisor, county extension agent and other knowledgeable people, and take advantage of their knowledge and experience.
- **Try new things.** If a particular IWM control program doesn't work, try a different combination of control techniques. Monitoring will show you when it is necessary to try different ways of controlling weeds.
- **Work with your neighbors.** Two heads and wallets are greater than one. Weeds do not respect land ownership or political boundaries. Weed management is one undertaking where cooperation can produce great rewards.
- **Don't let short-term success lull you into complacency.** Controlling weeds is an on-going management responsibility that will not disappear even if there are initial management successes. The goal is to learn from your successes and become more effective and efficient in the future.
- **Persistence is critical.** Most of the battle in managing weeds is in the act of being present for the fight every summer. Doing a little bit here and a little bit there every once in a while will not produce much in the way of results. Just think of all the weed seeds that are waiting for you to relax.

**Good luck!**

## REFERENCES

- Brown, M. L., C. A. Duncan, and M. B. Halstvedt. 1999. Cost and efficacy of spotted knapweed management with integrated methods. *Proceedings of the Western Society of Weed Science* 52:68-70.
- Bussan, A.J. and W.E. Dyer. 1999. Herbicides and rangeland. In R.L. Sheley and J.K. Petroff, eds. *Biology and Management of Noxious Rangeland Weeds*. Oregon State University Press, Corvallis, OR.
- Carpenter, A. T. 1997. Element stewardship abstract for tamarisk. The Nature Conservancy, Wildland Weeds Management and Research Program, University of California, Davis, CA.
- Colorado Natural Areas Program. 1998. *Native Plant Revegetation Guide for Colorado*. Colorado Natural Areas Program, Colorado State Parks, Colorado Department of Natural Resources. Denver, Colorado.
- Cooksey, D. and R. Sheley. 1997. *Mapping Noxious Weeds in Montana*. Montana State University Extension, Bozeman, MT.
- Elzinga, C. L., D. W. Salzer, and J. W. Willoughby. 1998. *Measuring and Monitoring Plant Populations*. Technical Reference 1730-1. Bureau of Land Management, National Business Center, Denver, CO.
- Hakim, S. E. A. 1979. *Range condition on the Threemile game range in western Montana*. M.S. thesis, University of Montana, Missoula, MT.
- Hastings, M. S. and J. M. DiTomaso. 1996. Fire controls yellow star thistle in California grasslands. *Restoration and Management Notes* 14:124-128.
- Heap, I. 1999. International survey of herbicide resistant weeds. Dr. Ian Heap, P.O. Box 1365, Corvallis, Oregon. <http://www.weedscience.com> [4 Feb 99].
- Hiebert, R. D. 1997. Prioritizing invasive plants for planning and management. In J. O. Luken and J. W. Thieret, eds. *Assessment and Management of Plant Invasions*. Springer-Verlag, New York.
- Hiebert, R. D. and J. Stubbendieck.. 1993. *Handbook for Ranking Exotic Plants for Management and Control*. Natural Resources Report NPS / NRMWRO / NRR-93 / 08. US Department of the Interior, National Park Service, Natural Resources Publication Office, Denver, CO.

- 
- Knopf, F. L. and T. E. Olson. 1984. Naturalization of Russian olive: implications to Rocky Mountain wildlife. *Wildlife Society Bulletin* 12:289-298.
- Lacey, J.R., C.B. Malone and J.R. Lane. 1989. Influence of spotted knapweed (*Centaurea maculosa*) on surface runoff and sediment yield. *Weed Technology* 3:627-631.
- Lym, R. G. 1998. The biology and integrated management of leafy spurge (*Euphorbia esula*) on North Dakota rangeland. *Weed Technology* 12:367-373.
- Montana State University. 1998. Weed mapping handbook. Montana noxious weed survey and mapping system. Version 1.9. Montana State University, Department of Plant, Soil and Environmental Sciences, Bozeman, MT. <http://www.montana.edu/places/mtweeds>.
- Mosely, J.C., S.C. Bunting, and M.E. Monoukian. 1999. Cheatgrass. In R.L. Sheley and J.K. Petroff, eds. *Biology and Management of Noxious Rangeland Weeds*. Oregon State University Press, Corvallis, OR.
- National Park Service. 1996. *Preserving Our Natural Heritage. A Strategic Plan for Managing Invasive Nonnative Plants on National Park system Lands*. US Department of the Interior, National Park Service, Washington, DC.
- Neill, W. G. 1997. Prescriptions for applying herbicide to tamarisk. *California Exotic Pest Plant Council News*. 5:7-10.
- Olson, B. E. 1999. Impacts of noxious weeds on ecologic and economic systems. In R.L. Sheley and J.K. Petroff, eds. *Biology and Management of Noxious Rangeland Weeds*. Oregon State University Press, Corvallis, OR.
- Piper, G. L. 1991. Principles of integrated noxious weed management. In *Proceedings of interagency weed management symposium, December 3-4, 1991*. Corvallis, OR.
- Randall, J. A. 1997. Defining weeds of natural areas. In J. O. Luken and J. W. Thieret, eds. *Assessment and Management of Plant Invasions*. Springer-Verlag, New York..
- Renz, M. J. 1999. Seasonal carbohydrate translocation patterns of perennial pepperweed (*Lepidium latifolium* L.) and its implications for control in California. In *Proceedings of the National Symposium on Tall Whitetop*. June 9-10, Alamosa, CO.
- Roché, B. F. and C. T. Roché. 1999. Diffuse knapweed. In R. L. Sheley and J. K. Petroff, eds. *Biology and Management of Noxious Rangeland Weeds*. Oregon State University Press, Corvallis, OR.
- Sheley, R. L., L. L. Larson, and J. S. Jacobs. 1999. Yellow starthistle. In R. L. Sheley and J. K. Petroff, eds. *Biology and Management of Noxious Rangeland Weeds*. Oregon State University Press, Corvallis, OR.

- USDA Forest Service. 1991. *Record of decision, noxious weed management, amendment to Lolo National Forest Plan*. USDA Forest Service, Lolo National Forest, Missoula, MT.
- Vitousek, P. M., 1986. Biological invasions and ecosystem properties: can species make a difference? In H. A. Mooney and J. A. Drake, eds. *Ecology of Biological Invasions of North America and Hawaii*. Springer-Verlag, New York.
- Whitson, T. D. 1999. Russian knapweed. In R.L. Sheley and J.K. Petroff, eds. *Biology and Management of Noxious Rangeland Weeds*. Oregon State University Press, Corvallis, OR.
- Wilson, E. O. quoted on page 8 in *SER News*, Volume 12, Number 1, February 1999. Society for Ecological Restoration, Madison, WI.
- Wilson, L.M. and J.P. McCaffrey. 1999. Biological control of noxious rangeland weeds. In R.L. Sheley and J.K. Petroff, eds. *Biology and Management of Noxious Rangeland Weeds*. Oregon State University Press, Corvallis, OR.